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ABSTRACT

This report provides a comprehensive statement of the Reagan administration's science and technology (S/T) policy and priorities. The report is organized into three chapters. Chapter I discusses S/T and United States society and the United States S/T policy. Highlights of the 1982 accomplishments in implementing the policy and of the fiscal year 1984 administration research and development (R&D) budget are included. Chapter II summarizes trends and developments in surface science, turbulence in fluids, lasers, robotics, genetics of complex organisms, molecular and genetic technology of plants, cell receptors for hormones and neurotransmitters, and neurobiology. Based on these examples, the chapter concludes with a discussion of possible implications for the organization and conduct of R&D and for the integration of results of these activities into society. Chapter III summarizes major S/T accomplishments in 1982 in a broad range of federal R&D programs. Areas considered include national security, space, health, energy, natural resources, environment, transportation, agriculture, and international cooperation. Included in an appendix is an analysis of R&D funding, highlighting R&D policies and trends in the 1984 budget and describing R&D programs of 13 agencies whose R&D obligations individually exceed $150 million. (JN)

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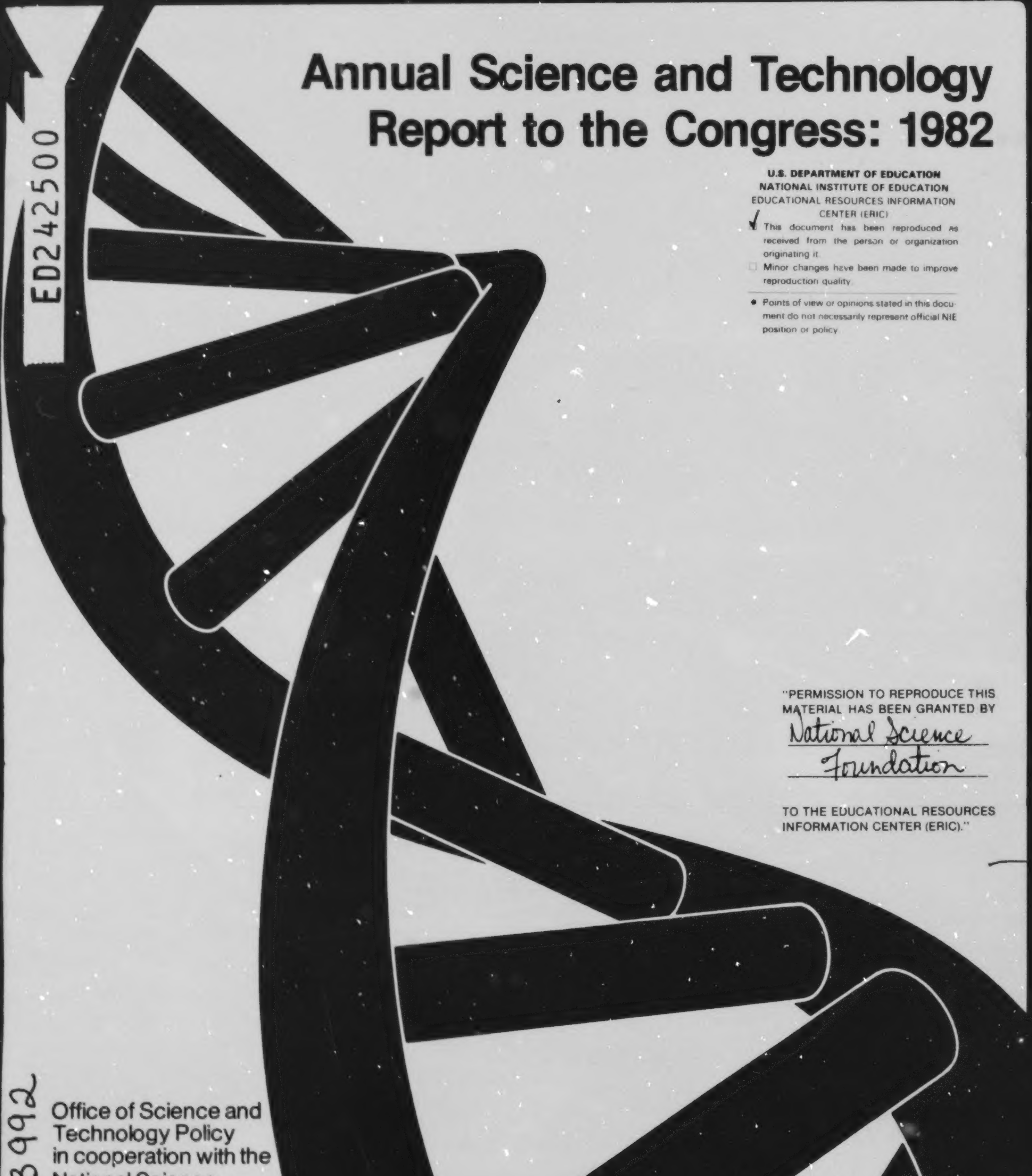

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Cover: *An artist's representation of the DNA double helix comprising the genes that direct production, growth, and life.*

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TO THE CONGRESS OF THE UNITED STATES

I am pleased to submit to the Congress the fifth *Annual Science and Technology Report*, as required under the National Science and Technology Policy, Organization, and Priorities Act of 1976, as amended.

Today the United States faces major challenges to both our economic well-being and our national security. We turn increasingly to science and technology to help us maintain the competitiveness of our industries in the international marketplace and to ensure the continued technological superiority of our defense capabilities.

The science and technology policies described in this report outline the framework in which our Administration is addressing these challenges. The significant increases in Federal R&D support, especially in basic research -- the fount of new technologies and new knowledge -- is evidence of our long-term commitment to strengthening the economy and security of America through science and technology. Programs to increase the supply of well trained scientists and engineers will ensure the best possible talent for continued technological advances in industry, universities, and government. The results of these important actions, in conjunction with the vigorous investment in research and development by the private sector, will be greater security and strong economic growth in the years ahead.

RONALD REAGAN

THE WHITE HOUSE,

October 3, 1983.

EXECUTIVE OFFICE OF THE PRESIDENT
OFFICE OF SCIENCE AND TECHNOLOGY POLICY
WASHINGTON, D.C. 20500

September 12, 1983

Dear Mr. President:

I am pleased to transmit to you, and through you to the Congress, your Administration's second Annual Science and Technology Report, as required by the National Science and Technology Policy, Organization, and Priorities Act of 1976, as amended.

The Report provides a comprehensive statement of our science and technology policy and priorities. As such it will serve as the basis for continued action in both the Executive Branch and the Congress.

Respectfully,

Jay Keyworth

G. A. Keyworth
Director

The President
The White House
Washington, D.C.

Chapter I

Decisions and Actions in Science and Technology

Department of Defense

This chapter presents the overall guidelines of the Administration's national science and technology policy. Major decisions and actions taken within those guidelines are described, and highlights of the research and development components of the President's fiscal year 1984 budget are noted. The chapter is divided into five parts:

- *Introduction*
- *Science and Technology and U.S. Society*
- *U.S. Science and Technology Policy*
- *Implementation of U.S. Science and Technology Policy: 1982 Accomplishments*
- *Highlights of Fiscal Year 1984 Administration R&D Budget.*

A researcher at the Army's Chemical Systems Laboratory conducts protein analysis studies.

Introduction

As the Administration continues to work toward economic revitalization and a strong national defense, the need for a firm science and technology base to achieve these two central national goals is more evident than ever. During 1982, the Administration continued implementation of its science policy, took actions to address the science and technology issues that emerged in 1981, and further defined the science and technology policy and the strategy for its implementation.

The U.S. science and technology enterprise still leads the world. In physics, chemistry, and physiology/medicine, U.S. scientists have won or shared 30 of 46 Nobel prizes during the past 10 years. Foreign countries continue to send their researchers and students to U.S. laboratories and research universities in quest of the latest knowledge and the best scientific and engineering training. Total U.S. expenditures for research and development (R&D) in 1982 are estimated to have been $79.0 billion. For comparison, in 1979 (the latest year for which there are data available for all countries), the United States spent $55.0 billion on R&D, compared to $56.3 billion by Japan, Germany, France, and Great Britain combined. In that year, the U.S. pool of scientific talent included 594,000 scientists and engineers engaged in R&D, compared to an estimated 273,000 for Japan and 270,000 for Germany, France, and Great Britain combined.

Notable U.S. accomplishments in science and technology during 1982 included the following:

- American citizens were awarded Nobel prizes in physics and economics.
- A mechanism was discovered through which certain viruses acquire their ability to cause cancer by capturing genes from normal cells and "corrupting" them. It follows that gene changes may be the basic cause of cancer. This new knowledge, combined with the recent isolation and characterization of the first virus associated with human cancer, contributes significantly to the effort to prevent and cure cancer.
- New methods were introduced to synthesize a "second generation" hepatitis B vaccine, thus overcoming the need for huge quantities of infected blood. The new methods open the possibility of producing pure synthetic vaccines for many other diseases.
- Research has demonstrated that brain function in aged laboratory animals is impaired by a reduction in the neurochemical substance acetylcholine. This is important knowledge in dealing with dementia—abnormal declines in memory and cognitive ability.
- Organisms were developed capable of breaking down, in laboratory conditions, the herbicide 2,4,5-T, which is very resistant to biodegradation. Further tests to determine whether the organisms will perform outside the laboratory and also break down compounds of the dioxin family will be conducted.
- The Department of Defense's NAVSTAR Global Positioning System is being used by the Coast Guard, the Department of Transportation, and the National Aeronautics and Space Administration to increase the safety and efficiency of transportation. NAVSTAR is a constellation of 18 Earth-orbiting satellites that can provide worldwide navigational coverage.
- The National Weather Service and the National Aeronautics and Space Administration implemented the Centralized Storm Information System, which allows rapid viewing and superimposing of satellite pictures for accurate storm visualization and tracking.
- The National Transonic Facility began operation. This facility will serve the R&D needs of the National Aeronautics and Space Administration, the Department of Defense, industry, and universities. It is probably the only facility in the world that permits testing of full-scale models at Reynolds numbers characteristic of critical flight regimes.
- On December 24, 1982, the most advanced of the two "mainline" magnetic fusion research programs, the Princeton Tokamak Fusion Test Reactor, achieved its first plasma. Construction of this major experimental facility will be completed in 1983, at which

point the basic physics research program will begin.

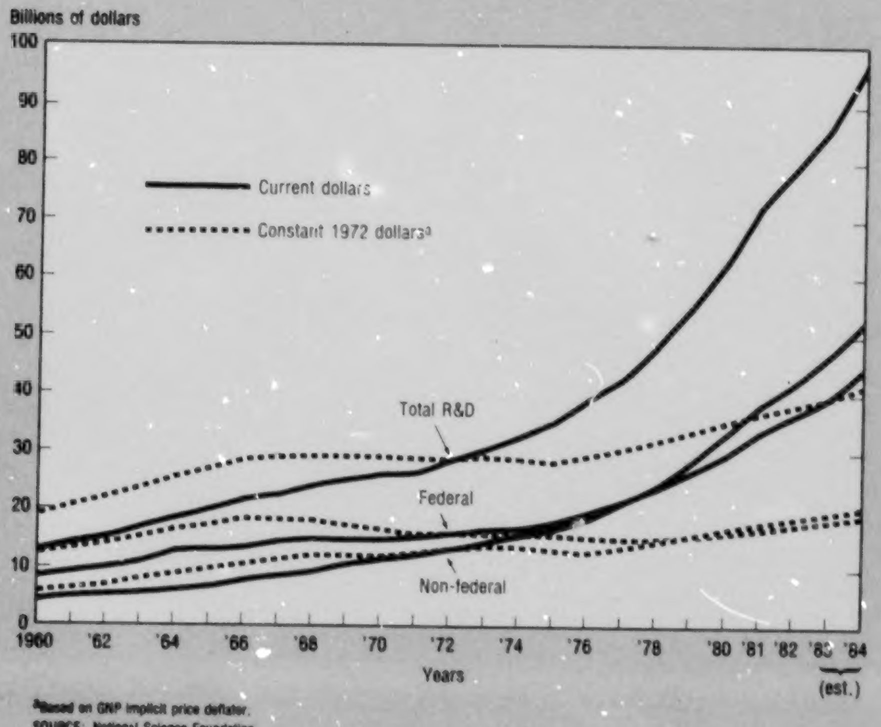
Science and Technology and U.S. Society

The Nation faces major new economic and defense challenges today. It is clear that we need new directions and new attitudes concerning U.S. science and technology in the 1980s and beyond. We must recognize that the United States is no longer building a science and technology capability, but rather is seeking to maintain its strength and improve its quality. Efforts to create that capability began during and following World War II and continued through the 1960s. During that period, quantity was the most important measure of achievement. Today, however, the U.S. science and technology enterprise is at a stage where adding more quantity would yield a smaller marginal return than improving quality.

The traditional U.S. approach to science and technology must be revised if we are to retain our international position. Our success in building and using our scientific and technical capability has led other nations, particularly those in the Organization for Economic Cooperation and Development (OECD), to emulate us and invest heavily in their science and technology base. Collectively, they now surpass us in annual spending for R&D. Thus, the United States must recognize that its future competitive edge lies in quality. The private sector is responding to this challenge through increased investment in R&D, as is the Federal Government (see Figure 1). It is worth noting that private R&D spending reached that of the Federal Government in 1978 and has exceeded it ever since. Today, Federal R&D spending is about 47 percent of the national total.

Although U.S. expenditures on defense R&D are substantial, total U.S. nondefense

Figure 1. National R&D Funding



^{a}Based on GNP implicit price deflator.
SOURCE: National Science Foundation

R&D expenditures (private and Government) exceeded those of our two principal competitors, Japan and West Germany, combined. Both defense and nondefense research lead to advances in knowledge that underpin a variety of national objectives ranging from national security to health. A recent survey showed that over the past 15 years the Department of Defense was second only to the Department of Health and Human Services in funding research that led to Nobel Prizes. In addition, the direct transfer of military-sponsored research to civilian application is well known, as, for example, in the development of microcircuitry and jet aircraft.

As international competition becomes keener and Federal budgets face tighter constraints, there is a greater than ever need to invest wisely. Federally sponsored R&D must be responsive to society's needs rather than be performed simply to satisfy intellectual curiosity. Thus, national policy must ensure that the U.S. R&D effort is adequate in quality, quantity, and direction.

In terms of quality, the Nation's education system must produce first-class scientists and engineers. Additionally, our R&D institutions must yield research results that open new frontiers of knowledge and new applications.

In terms of quantity, national R&D investments from both the public and the private sector must be adequate. The level of R&D productivity must be high, and high-quality scientific and engineering manpower, facilities, and equipment must be available.

In terms of direction, the Nation's R&D enterprise must emphasize areas that are most promising in meeting both near-term and long-term national needs. The R&D investment strategy must focus on technologies that will provide the basis for industries of the future as well as reinvigorate our "smokestack" industries.

U.S. Science and Technology Policy

The science and technology components of U.S. national policy are tightly linked; it is clear that without science there would be little technology in the modern industrial environment, and, without technology, science would rarely result in widespread benefits for our society. The most important common feature of science and technology policy is the recognition of the crucial role of people as the key elements of a science and technology capability.

The U.S. science policy is

- To enhance the contribution of science to the two most pressing long-term needs of the United States: national defense and the international competitiveness of U.S. industry;
- To maximize the return on national R&D investments; and
- To ensure the long-term vitality of the U.S. science and technology base.

The strategy to implement U.S. science policy

- Emphasizes excellence—in research results and in people;
- Stresses the importance of scientific relevance to national needs, and more clearly defines the appropriate roles of the Government and the private sector in supporting R&D;
- Facilitates cooperation in scientific research among Government, industry, and academia;
- Seeks to support sufficient basic and long-term applied research to ensure that the United States maintains the world's strongest science and technology enterprise;
- Emphasizes the importance of having the leading research universities in the world and of training the highest quality scientists and engineers to ensure continued U.S. qualitative leadership; and
- Allocates Federal R&D resources to support this strategy.

The U.S. technology policy is to ensure that U.S. scientific leadership results in economic and defense leadership.

The strategy to implement U.S. technology policy

- Provides tax and other incentives to the private sector for commercial R&D;
- Continues to emphasize the different private sector and Government roles in developing new technologies, products, and processes so as not to discourage private sector initiative with

the threat of Government intervention and competition;

- Improves the climate of cooperation so that maximum cross-stimuli occur among Government, industry, and academia;
- Improves the ability of Federal laboratories to contribute to U.S. industry, and also takes advantage of foreign research results;
- Encourages the change in industry's outlook to emphasize long-term viability rather than only short-term gain;
- Recognizes that the service sector in the U.S. economy is gaining in importance, and focuses emphasis on R&D accordingly; and
- Recognizes the effect of economic and regulatory policies on U.S. science and technology and, ultimately, on U.S. economic competitiveness.

In contrast to previous Federal policies that viewed increasing funding across the board as the key to success, the Reagan Administration has insisted on greater selectivity to maximize the public return on Federal R&D investment. From the beginning, the Administration's science policy has emphasized that funding of R&D must be contingent upon critical evaluation of excellence and pertinence; in other words, high-quality investigators, high-quality research, and results pertinent to the Nation's needs.

The criteria of excellence, pertinence, and appropriateness continue to be central to this Administration's science and technology policy. In addition, the important and differentiating feature of this policy, its focus on high-quality scientists and engineers as the key foundation of our science and technology capability, should be underscored. These scientists and engineers are the source of innovative ideas and the agents that translate those ideas into technologies, products, processes, and services. Only by maintaining a vigorous first-class scientific and technical talent pool can we maintain our science and technology leadership. Concurrently, the science and technology strategy strongly emphasizes the importance of having the leading universities in the world to train the highest quality scientists and engineers.

The science strategy seeks to support sufficient basic and long-term nonproprietary applied research to improve the Nation's science and technology enterprise, which remains the world's strongest. The strategy also recognizes the need for a strong Federal role in that support. Previous policies have failed in part to focus on the criteria of excellence, pertinence, and appropriateness and have paid too little attention to the role of people. These policies also distracted the Federal Government from its primary responsibility for R&D by extending Federal involvement into demonstration activities (for example, numerous energy technology demonstration projects) that do not satisfy the criteria.

The Reagan Administration has begun to return the Federal Government's attention to those research areas where it has the proper responsibility and capability. Thus, the Federal Government supports R&D activities to meet:

- Specific *Federal Government* needs, where the principal user of the R&D is the Government itself; for example, to support national defense; and
- Selected *national* needs, where the Federal Government shares responsibility with the private sector. Appropriate for Government funding in this category are R&D activities that improve the quality of life or support the Nation's long-term economic strength *and* are of such a nature that private firms or consortia acting alone cannot realize a sufficient return to warrant individual investment in them.

In particular, the Government will support research activities that result in new knowledge from which commercial technology may ultimately be derived. However, it is uniquely industry's role to translate this knowledge into commercial processes and products, and to support research and technology development where necessary to complement that supported by the Federal Government. Thus, the Federal Government might support experimental prototypes to identify key gaps in knowledge or to test predictions. However, the Federal responsibility does not include support for commercial prototypes, demonstration models, or subsequent engineering development activities. In addition, the Federal Government has the responsibility for ensuring that it does not stifle R&D activities in the private sector through poorly designed regulations, tax policies, or competitive projects.

Collaboration among Government, industry, and academia is emphasized in the new science and technology strategies. Past policies have not fully encouraged this collaboration. As a result, Government competed with private industry in many instances and funded R&D irrelevant to market and social needs in others. The situation is being corrected so that national investments in R&D will yield a higher return.

The science and technology policy and the implementation strategies described here require a strong partnership among Government, industry, and academia, with each understanding its responsibilities, assuming them to the fullest, and carrying them out competently. It is the Reagan Administration's intent to achieve this responsible partnership both through its own actions and through continued cooperation with industry and academia.

Implementation of U.S. Science and Technology Policy: 1982 Accomplishments

The *Annual Science and Technology Report to the Congress: 1981* identified and discussed several major science- and technology-related issues:

- Scientific and Technical Manpower
- University Research Instrumentation
- Federal Laboratories
- Industrial Research, Development, and Technological Innovation
- National Security
- Space Science and Technology
- Nuclear Energy
- International Activities

Two additional issues have been added in this report:

- Agricultural Research and Development
- Aeronautical Research and Technology

All of these issues were examined by the Administration during 1982, and actions consistent with the science and technology policy were taken to address them. To aid in this effort, the White House Science Council was established in February 1982 by the President's Science Advisor. Composed of representatives from universities and industry, the Council assists the Science Advisor in addressing science and technology issues and keeping abreast of changing perspectives in science and technology.

Scientific and Technical Manpower

A declining emphasis on science and mathematics education at the precollege level and a shortage of engineering faculty at universities have caused concern about the future availability of well-trained scientific and technical manpower. This concern led to several initiatives by academic institutions and private industry, particularly at the university level. It also led to many legislative proposals, most of which would result in major intervention by the Federal Government.

The Reagan Administration has opposed such intervention, in the firm belief that the Federal Government should be a leader and a catalyst, leaving the primary responsibility for major initiatives to the private sector and to local communities most familiar with their own requirements. Instead, Federal initiatives proposed to, and approved by, the Cabinet Council on Human Resources in 1982 were designed to be of modest cost and high impact. Through requirements for cost sharing by the private sector, the Administration ensures that these initiatives are relevant to the needs and interests of that sector. The initiatives include:

- A Precollege Science and Mathematics Teaching Improvement Program aimed at upgrading the knowledge and skills of secondary school teachers of mathematics, physical sciences, and biological sciences; this program includes actions to reward and motivate science and mathematics teachers, such as the Presidential Science and Mathematics Teaching Awards to be given to a distinguished secondary school teacher in mathematics or science from each State for demonstrated excellence in teaching; and

- Up to 200 Presidential Young Investigator Awards to be given each year to young faculty (within 7 years of Ph.D.) in scientific and engineering fields where demonstrated needs exist.

These programs address real shortages of high-quality technical manpower affecting the ability of key industries to compete with foreign firms and the sustained advance in U.S. technology for national defense. They demonstrate the importance of technically trained manpower, and complement and encourage private sector initiatives rather than compete with and discourage them.

University Research Instrumentation

Many of the instruments at U.S. research universities are growing obsolete. If left to continue, this obsolescence would affect the universities' ability to conduct research as well as to train future scientists and engineers. The solution must be found primarily by the research universities, with industry and the Federal Government playing a supportive role where appropriate. The national program organized in 1982 to assist universities in dealing with instrumentation obsolescence emphasizes collaboration among universities, industry, and Government.

Six Federal agencies (the Departments of Agriculture, Defense, Energy, and Health and Human Services, the National Science Foundation, and the National Aeronautics and Space Administration) will provide $303 million in fiscal year 1983 and $384 million in fiscal year 1984 for university research instrumentation. Through the Interagency Working Group on University Research Instrumentation, these agencies are assessing the state of university research instrumentation, taking initiatives within their research budgets to place greater emphasis on instrumentation, focusing small business funds on research instrumentation innovators, and making equipment and facilities at Federal laboratories more available to university researchers.

Universities, in turn, have accepted responsibility for improving their management of instrumentation and are initiating major efforts to encourage creative financing, equipment sharing, more responsive university regulatory policies, and adequate maintenance.

Industries, particularly equipment manufacturers, have, with the incentives of the Economic Recovery Tax Act of 1981, increased their contribution of instruments to universities. Some manufacturers have also agreed to give major discounts for equipment purchased by National Science Foundation grantees.

Federal Laboratories

A review of Federal laboratories was initiated by the Science Advisor because of concern that several obstacles were affecting the optimal use of the wealth of talent and equipment at the laboratories. These obstacles included a lack of clear mission in many cases, management problems, and insufficient synergistic relationships with industry and universities. A panel of the White House Science Council reviewed the major laboratories in the Departments of Energy, Defense, Health and Human Services, Agriculture, and Commerce, and the National Aeronautics and Space Administration, which accounted for 94 percent of the fiscal year 1981 R&D budget to Federal laboratories (according to a survey by the National Bureau of Standards). The panel made its recommendations to the President's Science Advisor in May 1983. On July 12, 1983, President Reagan accepted the panel's recommendations and approved a plan to implement them. He asked the Office of Science and Technology Policy and the Office of Management and Budget to oversee this effort.

Industrial Research, Development, and Technological Innovation

The Reagan Administration has sought to stimulate industrial R&D and technological innovation by clarifying antitrust policies, reforming patent laws and procedures, streamlining regulations, and providing tax incentives.

Uncertainties about Federal antitrust policy interpretation prevented many firms from entering into limited partnerships to conduct long-term, high-risk research beyond the capability of individual firms. In cooperation with the Office of Science and Technology Policy, the Departments of Commerce and Justice have been assessing the implications of Federal antitrust policies as they apply to cooperative research ventures, and they are preparing to issue new guidelines to encourage wider application of limited partnership arrangements to such ventures.

Currently, the average time required to obtain a patent is almost 23 months, and the Reagan Administration is seeking to reduce that time to 18 months. A fully computerized patent system is expected by 1990. To minimize the potential for costly and protracted litigation over patent validity and infringement, the Administration successfully encouraged passage of legislation that would facilitate voluntary arbitration of patent disputes. On February 18, 1983, President Reagan signed a Memorandum on patent policy that directs Federal agencies, within the limits of present laws, to permit any organization or business to retain patent rights on inventions made by that organization in the course of Government-funded R&D.

From the beginning, the Administration has sought to increase industrial productivity by relieving industry of unnecessary regulatory constraints. The President's Task Force on Regulatory Relief, chaired by the Vice President, was set up in January 1981. An Executive Order issued on February 17, 1981, established a set of basic principles to guide executive agencies in implementing regulatory statutes. On the Task Force, the President's Science Advisor chairs the Regulatory Work Group on Science and Technology, which includes representatives of five regulatory agencies. Its mission is to improve the scientific basis for regulation, and it is developing principles to guide the regulation of human carcinogens. The Work Group has also been reviewing information on the effects of formaldehyde on human health in order to formulate exposure regulations.

The President's Science Advisor will continue to work with the Task Force on Regulatory Relief to examine the capabilities and programs of the regulatory agencies and the basis on which these agencies make regulatory decisions. The Task Force's objectives are to improve the scientific capabilities of the agencies, to increase interactions among them, and to increase interactions between Federal regulatory scientists and scientists in universities and industry.

In January 1983, the Department of the Treasury published proposed regulations on Section 44f of the Internal Revenue Code, implementing Section 221 of the Economic Recovery Tax Act (ERTA) of 1981. This section provided a 25 percent tax credit for incremental R&D expenses. Preliminary data suggest that R&D equipment donations to colleges and universities under Section 222 of ERTA have significantly increased in 1982. The Administration is continuing to explore ways in which tax incentives can be effectively used to stimulate industrial R&D and innovation.

Agricultural Research and Development

The Administration has initiated a number of steps consistent with its overall science policy that are designed to strengthen the U.S. agricultural research system. In particular, the President's proposed fiscal year 1984 budget to Congress emphasizes support of basic research, increases funding through the competitive research grants program, and initiates a program of postdoctoral research fellowships designed to increase the flow of new, young scientists through the Agricultural Research Service (ARS) system. Further, the Department of Agriculture is implementing specific steps to consolidate and streamline ARS facilities and management, reduce the conduct and support of research of a commercial nature, and improve the relationship between Government and industrial scientists.

These steps are consistent with the conclusions reached by a group of experts from Government, industry, and academia convened in June 1982 by the Office of Science and Technology Policy and the Rockefeller Foundation to discuss the future of agricultural research in the United States. The group examined some widely expressed concerns about the state of U.S. agricultural research and reviewed the roles of various sectors and institutions in strengthening the country's agricultural research enterprise.

National Security

Science and technology are crucial to national defense, and the Reagan Administration has continued to evaluate the Nation's overall science and technology program to ensure that it is adequate to meet U.S. defense needs.

To this end, the Office of Science and Technology Policy examined several problems related to the defense mission:

- The adequacy of the National Defense Stockpile—much of the stockpiled material was acquired more than 20 years ago, and technological advances over time have changed the requirements for many industrial materials;
- The adequacy of U.S. monitoring technology for strategic missile verification and related R&D needs;
- The possible effects of electromagnetic pulses on communications between the National Command Authority and the Department of Defense;
- The need for a new nuclear fuel production reactor to replace aging plants and to provide additional material for nuclear weapons modernization; and
- The impact of Department of Defense programs in directed-energy weapons on strategic force modernization.

Space Science and Technology

In July 1982, the Administration announced a space policy that continues a balanced strategy of research, development, operations, and exploration for science, applications, and technology. Key objectives are:

- To preserve U.S. preeminence in critical space activities to enable continued exploitation and exploration of space;
- To conduct research and experimentation to expand understanding of (a) astrophysical phenomena and the origin and evolution of the universe through long-lived astrophysical observations; (b) the Earth, its environment, and its dynamic relationship with the Sun; (c) the origin and evolution of the solar system through solar, planetary, and lunar sciences and exploration; and (d) the space environment and technology to advance knowledge in the biological sciences;
- To continue to explore the requirements, operational concepts, and technology associated with permanent space facilities; and
- To conduct appropriate long-term research and experimentation in advanced technology and systems to provide a basis for future civilian applications by industry.

In addition, the policy provides that:

- The Government will provide a climate conducive to expanded private sector investment and involvement in space activities, with due regard to public safety and national security; and
- The Government will continue cooperation with other nations in international space activities by conducting joint scientific and research programs, consistent with technology transfer policy, that yield sufficient benefit to the United States.

In summary, the Administration's policy reaffirms the national commitment to the peaceful exploration and use of space in support of our national well-being.

Aeronautical Research and Technology

Following a review of the Government's role in support of aeronautical research and technology (R&T), the President's Science Advisor reaffirmed the long-standing Federal policy to support such R&T in the national interest. The review specifically recognized that large gains are expected from continued aeronautical R&T and that such gains are important for U.S. national security and the continued safety and efficiency of our air transportation system. The review further recommended that Government support for aeronautical R&T and for military aeronautical technology demonstration be consistent with overall Government priorities.

Nuclear Energy

In October 1981, President Reagan issued a nuclear policy statement that strongly endorsed nuclear energy, not as an energy source of last resort, but as one of the best potential sources of electrical energy supply for the coming decades. The five major elements of this policy are:

- Improvement of the regulatory and licensing processes for nuclear facilities;
- Continued development of breeder reactor technology, including construction and operation of the Clinch River Breeder Reactor;
- Resumption of commercial fuel reprocessing in the United States;
- Early deployment of facilities for storing and disposing of commercial high-level radioactive wastes; and
- Identification and removal of deeply rooted obstacles to the increased use of nuclear energy.

The Administration supported a nuclear waste bill that set up the mechanisms and procedures for selecting nuclear waste disposal sites. In January 1983, the bill was passed by Congress and signed by the President.

During 1982, the following actions were taken by the Office of Science and Technology Policy to implement the President's nuclear policy:

- An examination of the current Government-operated uranium enrichment business, the possibility of transferring those activities to the private sector, and the operating strategy for existing gaseous diffusion plants;
- The establishment of an interagency study group to examine incentives for private sector reprocessing of spent nuclear fuel, and consideration of buying plutonium fuel for Federal research reactors from a private sector operator of the Barnwell reprocessing plant; the latter will be reexamined in light of the Nuclear Waste Policy Act of 1982;
- A review of standards proposed by the Environmental Protection Agency (EPA) for high-level radioactive waste disposal; the Agency has published the standards for comment; and
- A review of standards proposed by EPA for the cleanup of 24 inactive uranium milling sites in the United States, including reconsideration of radiation limits and changes in the methodology of risk assessment; the Agency has published the final standard.

International Activities

The *Annual Science and Technology Report to the Congress: 1981* stressed that the international cooperative programs in which U.S. participation is federally supported must be consistent with the President's commitment to maintain fiscal responsibility in the public sector and enhance incentives for private sector investment. All U.S. research projects are subject to the same criteria of excellence, relevance, and appropriateness. The application of these guidelines to cooperative science and technology programs with individual countries depends on the specific scientific concerns that the United States shares with the country; on the country's science and technology policies, resources, and capabilities; and on U.S. foreign policy regarding that country.

In 1982, the President's Science Advisor laid the basis for enhanced international cooperation on large-scale research projects, beginning with Western Europe and Japan. In June 1982, at the Versailles Economic Summit in France, a Working Group was established to prepare a report on technology, economic growth, and employment. The Science Advisor led the U.S. delegation in this effort. The report was released in March 1983. It considers the opportunities, problems, and challenges presented by technology and analyzes the relationship between technology, economic growth, and employment. It also offers a number of recommendations on several problems, such as lowering trade barriers among Summit nations in high technology products and restricting transfer of militarily significant technology to Soviet Bloc countries. In addition, the report identifies 18 projects for international cooperation. The United States has proposed five of them and will serve as lead country for their implementation. These are high-energy physics, remote sensing from space, solar system exploration, fast breeder reactors, and controlled thermonuclear fusion. In May 1983, the leaders at the Williamsburg Economic Summit issued a declaration that, among other things, noted with approval the Working Group report and commended the progress made in the 18 cooperative projects. Implementation and coordination of these projects is under way.

At the President's request, the Science Advisor designated a group of U.S. scientists to explore greater cooperation with India in food production, health, biomass for energy, and materials sciences. The U.S.-India Senior Scientific Panel was commissioned during Prime Minister Gandhi's visit to the United States in July 1982. The Panel reported its recommendations for specific collaborative programs to the President and Prime Minister in the spring of 1983.

At the October 1981 Summit Meeting in Cancun, Mexico, the President offered the help of U.S. experts in agricultural science and agribusiness to developing countries. Presidential Agricultural Development Task Forces were set up, and, in 1982, they visited five countries: Peru, Thailand, Honduras, Venezuela, and Liberia. The Agency for International Development and the Department of Agriculture are implementing the recommendations of the Task Forces and encouraging continued cooperation. Five additional countries will be visited in 1983.

The Science Advisor assisted the National Security Council in monitoring official U.S.-U.S.S.R. exchanges, which were reduced following the Soviet invasion of Afghanistan and again following the imposition of martial law in Poland. As one component of the U.S. Government sanctions announced by the President in December 1981, three U.S.-Soviet cooperative agreements due to be renewed in 1982 (Science and Technology, Energy, and Space) were permitted to expire. The renewal of other U.S.-Soviet agreements will be reviewed on a case-by-case basis.

The Science Advisor headed a high-level U.S. delegation to the third meeting of the U.S.-P.R.C. Joint Science and Technology Commission in May 1983. At this meeting the United States and the People's Republic of China reviewed progress in existing areas of cooperation and exchanged views on future activities. At the conclusion of the meeting, three new protocols on cooperation in Nuclear Physics and Magnetic Fusion, Aeronautical Science and Technology, and Transportation Science and Technology were signed. These add to the 17 existing protocols in such areas as agriculture, student and scholar exchanges, high-energy physics, and hydropower. In addition to the new accords, a Memorandum of Understanding on cooperation in the basic biomedical sciences was signed. These new accords build on an established base of science and technology programs that are making excellent progress.

Following the President's visit to Brazil in December 1982 and his invitation to Brazil to cooperate in the Space Shuttle effort, several working groups were set up to further U.S.-Brazilian scientific and technical cooperation.

Highlights of Fiscal Year 1984 Administration R&D Budget

Summary of Past Trends and Fiscal Year 1984 R&D Budget

Federal R&D obligations rose from $37.6 billion in fiscal year 1982 to $40.1 billion in fiscal year 1983. As it continues to recognize the need to maintain a strong science and technology base, the Reagan Administration has proposed $47.0 billion for Federal R&D in fiscal year 1984, a 17 percent increase over 1983. The 1984 proposed budget for R&D reflects national priorities in three major ways:

- Defense R&D, consistently neglected for 20 years, is increased by 29 percent. The proposed R&D budget for the Department of Defense includes $867 million for basic research.
- Basic research funding increases by 10 percent to $6.6 billion. The physical sciences and engineering, underfunded since the 1960s, receive large, selective increases.

- Much of the increased basic research is directed to universities, where it will help train new scientists and engineers.

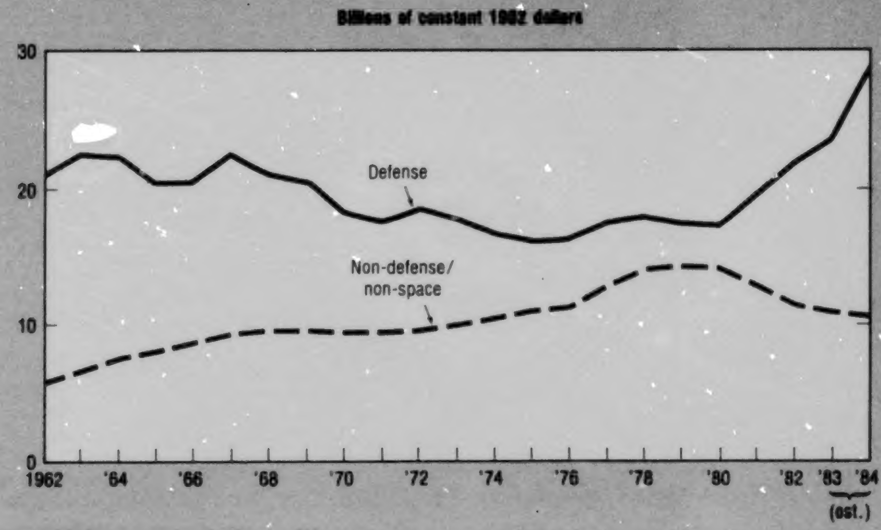
As in fiscal year 1983, the Department of Defense accounts for a large share of the Federal R&D budget, reflecting the Administration's continued effort to reestablish some balance following the sharp decline in defense R&D since the 1960s, during which time civilian R&D increased dramatically (see Figure 2). Defense R&D expenditures in fiscal year 1983, in constant dollars, exceeded for the first time the total last reached in 1967. If the previous decline were allowed to continue, it would deprive the United States of the key science and technology leadership that has allowed us to match the quantitative arms buildup by rival countries with quality, i.e., technologically advanced weapons. Emphasis on quality over quantity is also likely to benefit U.S. society at large through technology spinoffs from military R&D to the civilian sector.

For fiscal year 1984, proposed total funding for basic research increases by 10 percent over 1983 to $6.6 billion. Fundamental changes in the funding pattern will result from the greater selectivity exercised in the budget process. Basic research goes up 15 percent in agencies primarily supporting physical sciences and engineering, compared to 3 percent for agencies primarily supporting life and other sciences.

Those physical science areas such as mathematics, physics, chemistry, engineering, materials science, astronomy, and space sciences in which basic research is most likely to have the greatest long-term impacts on new technologies are particularly emphasized. For example, funding has been provided for construction, at an accelerated schedule, of the high-energy physics "linear collider" facility at the Stanford Linear Accelerator Center to test the validity of current scientific theories on basic forces in nature and to maintain U.S. preeminence in this field.

Much of the increased funding in basic research will go to universities, where it will contribute to production of future scientific talent as well as expansion of knowledge, consistent with the emphasis on increasing and maintaining an adequate supply of first-class scientists and engineers. The 1984 R&D budget also provides for initiatives, described earlier, to strengthen science and

Figure 2. Federal obligations for defense and non-defense/non-space R&D



NOTE: Estimates are shown for 1983 and 1984
SOURCE: National Science Foundation

engineering education and to improve and to expand research facilities and equipment at universities. In addition to $30 million in the President's Department of Defense budget and $6 million in the Department of Energy budget for instrumentation at universities and affiliated centers, the President's 1984 National Science Foundation budget for instrumentation and equipment will be $108.1 million (*not* including $12.1 million for instrumentation for the antarctic program that is not "university" instrumentation), a 59 percent increase over 1983. Major projects at universities will also be undertaken, such as upgrading the accelerators at Yale and the University of Washington.

The competitiveness of U.S. industry depends on how effectively research results are translated into new technologies. This process requires much greater cooperation among universities, industry, and Government. Several initiatives aim to encourage this cooperation:

- The capacity of the National Synchrotron Light Source at Brookhaven National Laboratory will be expanded to allow greater access to this unique national facility by industry and university users.
- A supercomputer-based numerical modeling capability for aerodynamics research will be established at the Ames Research Center. This will improve aircraft aerodynamic design techniques and also contribute to research in other disciplines, for example, climate studies, that use numerical modeling.
- A materials science center to be established at Lawrence Berkeley Laboratory will improve the linkages between R&D-performing institutions and better serve the scientific needs of the country in high technologies.

Special Analysis K by the Office of Management and Budget discusses the Federal R&D budget in more detail and is included in the Appendix.

Fiscal Year 1984 R&D Budget by Agency

The R&D authorizations proposed for the major agencies in President Reagan's fiscal year 1984 budget are briefly summarized below.

Department of Defense (DOD). Department of Defense obligations for the conduct of R&D would total $29.9 billion, a 29 percent increase over 1983. Of this total, $867 million would be for basic research, or a 13 percent increase over 1983. R&D facilities would be allocated $438 million, up from $323 million in 1983. The DOD R&D activities would address such areas as microelectronic devices, materials, and advanced computer languages, as well as advanced strategic and tactical weapons and communications.

National Aeronautics and Space Administration (NASA). National Aeronautics and Space Administration R&D obligations decreased by 1.3 percent from the 1983 level to $2.5 billion, due to the spending patterns of previously initiated projects and increased reimbursement for Shuttle flights. The obligations for basic research would be increased by 13 percent to $682 million, consistent with the Administration's science and technology policy. The proposed R&D budget for NASA would provide for continued U.S. leadership in critical aspects of space science. The main purpose of NASA's space R&D activities is to provide new knowledge about the earth, the solar system, and the universe, leading ultimately to new space applications for commerce and defense.

The Explorer Satellite Program will provide a highly cost-effective and flexible means to pursue important new space science opportunities covering a wide range of objects and nearly every region of the electromagnetic spectrum. It will support the completion of the Active Magnetospheric Particle Tracer Explorer as well as continued development of the Cosmic Background Explorer. Development of the Extreme Ultraviolet Explorer and definition of the X-Ray Timing Explorer will begin. An example of a key planetary exploration program funded in this budget is the Venus Radar Mapper, a successor to the Venus Orbiting Imaging Radar mission. It demonstrates that strong and scientifically exciting planetary missions can be developed at manageable cost and scientific risk. The Venus Radar Mapper will obtain data to explore a number of fundamental scientific questions about the origin and evolution of the solar system.

In addition, planned development of major projects, such as the Space Shuttle, the Space Telescope, and the Gamma Ray Observatory, and space flight missions already launched (for example, the two Voyager spacecrafts) would be continued.

Finally, NASA R&D funding also emphasizes such fundamental aeronautical disciplines as fluid and thermal physics, materials and structures, propulsion, and computational capabilities to maintain long-term U.S. leadership in aeronautics.

Department of Energy (DOE). The 1984 energy-related R&D obligations, totaling $4.7 billion, cover a broad mix of programs including development and testing of nuclear weapons, basic research in high-energy physics and nuclear sciences, and long-term energy R&D. They reflect increased emphasis on development of new knowledge and on reduction of Federal involvement in technology development and demonstration activities. Obligations for basic research would increase by $160 million, or more than 18 percent over 1983, to $1021 million in 1984. A university instrumentation initiative would provide $6 million for the purchase of state-of-the-art scientific research equipment for the major research universities. The 1984 budget request for R&D facilities would be $501 million and would fund the upgrading and construction of several of the projects at universities and national laboratories described earlier.

Department of Health and Human Services (HHS). Proposed obligations of $4.4 billion for the conduct of R&D by the Department of Health and Human Services represent a 2 percent increase over 1983. Within this total, funding for basic research would increase by $54 million to $2.2 billion. R&D facilities would account for $29 million.

About 87 percent of the Department's funds for R&D (excluding facilities) and over 93 percent of the Department's basic research funds are obligated by the National Institutes of Health for biomedical research to advance the Nation's capabilities for prevention, diagnosis, and treatment of disease. The remainder of the HHS R&D funding would support health research and developmental and social research by other agencies within HHS.

National Science Foundation (NSF). The 1984 National Science Foundation proposed budget includes $1.2 billion in obligations for the conduct of R&D, or 17 percent above 1983. Within this budget, basic research support would increase by about 18 percent.

The 1984 proposed budget would support initiatives to improve education in mathematics and science and would provide for upgrading research instrumentation at universities. These funds would also emphasize research to advance knowledge in such disciplines as mathematics, materials science, astronomy, and electrical, computer, and chemical engineering, which present exceptional opportunities for scientific and technological advancement in the long term. The increase in support for mathematical sciences would allow funding of additional graduate students and postdoctoral researchers, as well as enhanced research activity in computational mathematics and theoretical computer science. The increase in astronomy support would allow preliminary design studies for the Very Long Baseline Array (VLBA) of radiotelescopes. This instrument makes possible extraordinarily high angular resolution observations of the currently enigmatic central regions of quasars and allows determinations of the size of our galaxy by entirely new methods. Using largely proven technology, the VLBA is regarded by the astronomy community as an extremely important new ground-based facility.

Finally, the NSF budget would continue to support the U.S. antarctic and ocean drilling programs.

Chapter II

Outlook for Selected Fields of Science and Technology

National Institutes of Health

This chapter presents a discussion of opportunities for scientific and technological knowledge to make significant contributions to the achievement of Federal program objectives and national goals. The chapter is based on a review of trends and developments in eight selected fields of science and technology that was carried out under the auspices of the Committee on Science, Engineering, and Public Policy of the National Academy of Sciences (NAS).

The eight topics reviewed by NAS and summarized in the first part of this chapter are:

- *Surface Science and Its Applications*
- *Turbulence in Fluids*
- *Lasers*
- *The Next Generation of Robots*
- *The Genetic Program of Complex Organisms*
- *The Molecular and Genetic Technology of Plants*
- *Cell Receptors for Hormones and Neurotransmitters*
- *Neurobiology*

Based on these eight examples, the chapter concludes with a discussion of possible implications for the organization and conduct of research and development and for the integration of the results of these activities into society. The discussion of these implications is organized under four headings:

- *The Emergence of Research-Based Technologies*
- *The Pace of Technological Innovation*
- *The Importance of Improving Scientific and Technical Communications*
- *The Dissolution of Disciplinary Boundaries*

A patient receives laser treatment for the neovascular form of aging related maculopathy.

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Summary of Trends and Developments in Selected Fields

Surface Science and Its Applications

Surface science is concerned with the first few atomic layers at the surfaces of solids and examines the effects of those layers on the rest of the solid and on other materials. All solids, natural or synthetic, have surfaces, and the character of those surfaces—their structure, their electronic nature, the atoms that they are composed of—can influence the physical and chemical behavior of the entire solid and the interaction of the solid with other atoms and molecules and with external radiation.

Surface science has made great strides during the past decade or two, establishing itself as a basic science capable of experiment and theory that provide detailed understanding at the atomic level. But much remains to be done, both to continue the development of the science itself and to provide a strong base for the important technologies in which surface phenomena figure prominently.

One of the most important tasks facing the surface scientist is to build detailed understanding of chemical reactions at surfaces. The preparation of chemical reactants in specific vibrational and rotational states and the resolution in time of surface processes are new means to this end. Considerable refinement of our techniques for determining the geometrical, electronic, and vibrational structures of both the surface and the species adsorbed on it is in the offing. Improvement in catalytic and energy efficiency can be expected, for example, in such diverse catalytic processes as the production of fertilizers, polymers, refined petroleum, and synthetic fuels.

Another important facet of surface science concerns the role of the geometrical and electronic properties of surfaces in the design, fabrication, and operation of high-speed integrated electronic circuits. The technology will involve further development of multilayer structures having high electron mobility, interfaces or junctions of improved electrical properties, and means of rendering specific surfaces of the new materials passive. Central to an emerging high-speed integrated circuit technology is the fabrication, by molecular beam epitaxy (MBE), of transistors involving well-defined layers of differing atomic composition that are thin enough to permit appreciable spillover of electrons between layers. This new technology will provide logic circuits for higher speed computers, for example. Similarly, optical communication systems will be improved by the extension of MBE techniques to produce semiconducting structures required for lasers and optical detectors in previously inaccessible wavelength ranges.

Our understanding and control of many metallurgical problems of great economic import will be advanced by the use of surface analytical tools. Chemical corrosion, as an example, is a very costly phenomenon occurring on bridges and in nuclear reactors. Detailed knowledge of the process is essential to the design of corrosion-resistant materials or corrosion-preventing coatings. Expensive, empirical, trial-and-error solutions must give way to ideas based on understanding of the relevant phenomena at the atomic level.

The science of surfaces and interfaces is a multidisciplinary endeavor fundamental to many important technologies in addition to those touched on in this brief look at the future. Often, it is difficult to detect what is science and what is technology and which of these in any particular instance is more important to the enrichment of the other.

Turbulence in Fluids

Moving fluids tend toward turbulence, whether they are air, blood, ocean water, the aerosols of clouds, the oil flowing in pipelines, the lithosphere of drifting continents, or galaxies. Turbulence is disordered fluid flow, and understanding what initiates and maintains it is essential to better prediction and control of turbulent events.

The discovery in recent years of mechanical and exactly solvable mathematical systems that lead to chaotic behavior suggests new paths toward understanding turbulence in fluids, whether gases or liquids. Turbulence is the cause of bumpy airplane rides, the rapid mixing of chemicals in industrial processes, the enhanced drag on petroleum flowing in pipelines, and many other phenomena that can be either desirable or undesirable. Scientists and engineers concerned with turbulence are beginning to think more about the mechanism involved, as opposed to its statistical manifestations—more about what actually happens in the fluid, as opposed to statistical approximations of what happens. Such work is yielding a new scientific language—a new way of thinking about turbulence—that promises deeper understanding in the search for universally applicable features of the turbulent process.

Statistical approximations, based on experimental data, are necessary because we have no other way of dealing with turbulence in engineering design and for other practical purposes. After more than 100 years of scientific study, the theory of this immensely complex process has yielded negligibly few quantitative predictions of turbulence. The trend toward mechanistic thinking will not, soon, bring complete or even close to complete understanding of the central problem of fully evolved turbulence. But it offers every hope of leading to the construction of statistical hypotheses that reflect more accurately the underlying mechanisms of the process.

For the near and intermediate term, the goals are to increase our skill at controlling instabilities and to achieve a broad predictive capability for statistical models of turbulence. Such capability would permit both energy savings and improved performance in redesigned pumping systems, compressors, turbines, aircraft, chemical reactors and mixers, and many other products. New understanding of the limits on predictability of the large-scale disorder in weather and in ocean currents can be an early reward of studies of chaos in simpler systems. New awareness of the origins of disorder in natural processes may ultimately be as important a contribution to model building in economics, political science, and ecology as it is to fluid turbulence.

Lasers

Lasers are devices in which atoms, molecules, or ions are made to radiate at frequencies corresponding to separations between their discrete energy levels. The product is light of essentially a single wavelength and phase—coherent light.

Such light is monochromatic, or of one color; highly directional, emerging as a narrow and focused beam; and intense. The wavelength range of laser light has widened considerably in the 25 years since the laser was invented, and many new and novel applications have emerged. In the next several years, both the uses of lasers and their capacities will expand. Lasers are remarkable, not only for what they have done, but for what they now seem on the verge of doing in a range of important applications, extending from lightwave communications to new surgical techniques and medical diagnostic applications to the separation of uranium isotopes.

Existing lasers meet the needs of science and technology over much of the electromagnetic spectrum. New types are needed, however, especially types that produce light of shorter wavelengths and pulse durations than are available today. Tunable lasers should be able to cover the low end of the spectrum to wavelengths as short as 500 angstroms in the far ultraviolet region of the spectrum within the next few years, and pulse durations shorter than 30 trillionths of a second are in prospect.

Existing lasers have become an essential tool for expanding our knowledge of matter, and new types expected soon will provide the basis for an even deeper understanding. High-resolution laser spectroscopy, for example, is helping to confirm the theories of quantum electrodynamics. The same laser methods are contributing steadily to our knowledge of the structure and behavior of solid materials used in electronic and other kinds of devices.

The technology of lightwave communications—the transmission of information by laser light through small optical fibers—is also advancing rapidly. Many systems using first-generation technology are operating, and second-generation technology is well along in development. A prototype system has operated over 101 kilometers of optical fiber at a high data rate and essentially zero error rate.

Lasers are used in industry for many purposes, including drilling, cutting, welding, and surface treatment. In many of these uses, laser processing schemes are peculiarly well adapted to computer-controlled technology. The changes caused by the advent of lasers in industry are likely to accelerate in the near future.

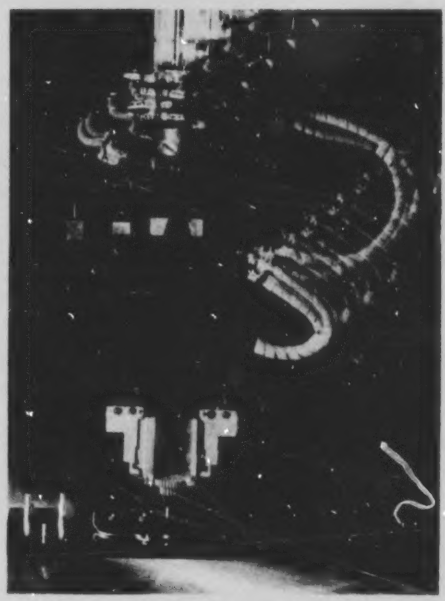
Defense applications of lasers include laser radar and laser target designators. The use of lasers as weapons is complicated by many difficulties, but the field is extremely active. Progress is likely to come in unexpected areas involving specialized applications. Lasers can be used to separate the isotopes of chemical elements, and an isotope-separation process for nuclear fuel and weapons is scheduled for major scale-up. It promises to produce in a single step the enrichment now achieved in the costly, multiple-step, gaseous diffusion process.

Lasers have made considerable progress in medicine, for both diagnosis and surgery, yet the surface has barely been scratched. In addition to many existing applications, the use of a carbon dioxide laser for noninvasive analysis of blood for sugar, urea, and lipids has been demonstrated. The invention of an articulated arm that uses hollow quartz tubes as waveguides is likely to revolutionize carbon dioxide laser surgery in the next 5 years.

The Next Generation of Robots

Robots are computer-controlled devices that reproduce human senses, manipulations, and motions well enough to do useful work. They are now being installed in manufacturing plants, and, in the next several years, major expansion of their uses and capacities will occur.

Although the sensory and manipulative capabilities of industrial robots and their ability to handle unexpected events are still quite limited, robot technology is strengthening and expanding rapidly. Initial commercial success has been achieved through robot mastery of such commercially important operations as spot welding and spray painting. The microelectronics revolution can also be expected to accelerate the development of robotics by supplying many "miracle chips" embodying advanced sensory and control functions.



IBM Systems Products Division

A time-lapse photograph of a robot manipulator assembling gears. The device can sense and correct improper seating of the gears.

While robots will only come to perform more industrial operations gradually, their potential near-term uses are extensive. Most favorable for robot application at the moment is the manufacture of items in batches substantial enough for hand manufacture to be undesirable but not large enough to warrant heavy capital outlays on fixed automation. Robotic research is proceeding actively in France, West Germany, Sweden, Japan, and the United States, but Japan leads in the use of robots. Operating industrial robots in 1980 numbered 11,250 in Japan and 4,370 in this country.

Much of the robotic equipment used by industry today is too crude to respond flexibly to changing situations. Much more sophisticated control languages are needed to make industrial robots easy to use and more versatile. Desirable new robot language features include, for example, statements that can cause a manipulator arm to move between specified positions while automatically avoiding certain obstacles or undesirable configurations. In general, we can expect advances in robotic technology to be reflected by the addition of new statements to robot programming languages.

More sophisticated sensory functions, for example, improved image-analysis software, represent another important direction. These sensory capabilities will need to be integrated with manipulator-control software to produce useful industrial closed-loop hand-eye systems.

At present, software for analyzing visual data acquired by robots is not especially reliable and is quite expensive computationally. Improved scene-analysis algorithms are needed if we are to have vision systems that can easily be reprogrammed for a wide range of applications. Deeper understanding of the algorithmic nature of such systems will encourage development of high-performance electronic chips able to handle the required operations very rapidly. As such chips become available, the range of objects that can be inspected economically by robot equipment will expand.

The limited capabilities of present industrial robots indicate that we are far from being able to create general-purpose household robots, which would require sensing and command capabilities far exceeding those needed by industry. Still, it may soon be possible to design robots to perform such relatively simple housekeeping tasks as sweeping large public spaces or mowing lawns. A related possibility is computer-controlled agricultural equipment such as plows and cultivators.

Robots can be expected to continue to take over hazardous, repetitive, and menial tasks and to contribute significantly to the progress of industrial automation under way in this country for the past century. At the same time, robot technology is likely to make certain jobs obsolete while creating others. In the absence of adequate mechanisms for adjusting to this change, severe social tensions may result. The Nation faces the critical task of assessing and alleviating these developing problems, while taking advantage of the ability of robots to enhance productivity and international competitiveness, thereby preserving jobs that might otherwise be lost.

The Genetic Program of Complex Organisms

Until the early 1970s, the direct study of the structure of genes was essentially limited to the DNA of bacteria and viruses, and even that was restricted. The sheer complexity of the DNA of plants and animals, some millions of times larger than that of simple viruses, precluded more than a glance at its organization and a few hints at how it functioned. We knew that the vast genetic system encoded in DNA included the information stored in genes in the form of the genetic code. We also knew that other DNA segments were important in regulating the time and the place in the body where the genes yield up their information in the form of proteins, which account for the structure and metabolic capabilities of cells and organisms. But we were stymied.

Then, with the development of recombinant DNA techniques and, contemporaneously, greatly improved methods for the manipulation of DNA molecules, the picture changed dramatically. As a result, we have learned a great deal about the DNA of plants and animals, including man. We have been surprised to learn how different these complex organisms are from bacteria. For one, the genes in complex organisms are interrupted by other extraneous segments of DNA. Somehow, before the gene can function, the interruptions must be removed and the separate pieces of the gene spliced together. For another, the DNA segments that turn genes on and off at particular times and in particular places in the body are very complex, often composed of several modules that are not even close neighbors of the gene or of one another. And it now seems that genes themselves make up only a portion of the DNA. As much as 20, 50, or even 90 percent of the DNA in different organisms has no known function as yet, and perhaps none at all.

Thirty years ago, genetic experiments with corn hinted that some parts of the DNA might be in flux, with DNA segments capable of moving about from one place to another in these large molecules. Now, we know that this is a general phenomenon, and, in some cases, the events have been studied at the molecular level. Yet, we do not know the biochemical mechanisms involved in the movement, nor do we understand the implications of these mobile DNA segments. The biological process of development of a full plant or a complicated animal from a single cell is now thought of as a precise program in which different genes are turned on and off in orderly fashion at different times and in different kinds of cells. In the case of antibody formation, the developmental program includes precise rearrangements of the DNA sequences themselves.

All of this new knowledge answers a few long-standing questions, but raises an even greater number of new ones. As usual, in science, the most important outcome of the new knowledge is the revelation of unsuspected levels of ignorance. The next 5 years are likely to see progress in understanding splicing, the significance of movable elements, and the signals that turn genes on and off in response to genetically programmed changes or altered cellular environments. These processes are of much more than academic interest. Increasingly, it is becoming apparent that the proper regulation of gene activity is fundamental to healthy organisms, be they crops, important animal food sources, or human beings.

It also appears that rearrangements in DNA may prove to be a common element in the diverse causes of tumors, including chemical carcinogens and viruses. Single genes that cause a normal cell to turn into a tumor cell are being studied. Many of these are a normal part of the DNA of the living host organism. What regulatory changes account for the conversion of a normal gene to a tumor gene? We are coming to understand that many diseases often have heritable components—if not the diseases themselves then a propensity toward them or an inability to defend the body against them.

The past decade has been marked by an extraordinary pace of accomplishment. The techniques are in place and are being improved constantly. Many of the questions that need probing are clear. The next 5 years will provide some of the answers and will surely reveal a new generation of questions. At the same time, the new knowledge is likely to be turned toward imaginative solutions for long-standing problems. New and better chemicals for manufacturing are likely to be produced, new and better drugs and vaccines are likely to be manufactured, new and improved plants may be developed, and diagnosis of diseases will almost certainly be improved. With understanding also may come improved treatments for diseases that have resisted past efforts.

The Molecular and Genetic Technology of Plants

Application of the new techniques of molecular genetics to plant science offers unique possibilities for manipulating plant genes to achieve the long-range objectives of agricultural crop improvement. However, the first requirement is to understand plant gene regulation as it relates to gene structure. Currently, we understand little of the language in which instructions for gene regulation are encoded. A first objective therefore must be the study of several important plant genes to allow us to understand their regulatory signals. With this understanding, we should be in a far stronger position to confront the increased demands for food and fiber resulting from population increases and improvements in living standards.

Some of the demand will have to be met by bringing marginal lands into production. The successful use of such land will require the development of crops that thrive under less than ideal conditions and the adaptation for cultivation of such now underutilized plants as grain amaranth and the winged bean. Given the rising worldwide demand for agricultural products and the fact that modern agriculture is based largely on crops known and cultivated thousands of years ago, the potential of new inquiries into plant genetics and development is enormously significant.

Indeed, the advances in genetic knowledge of the past few years promise ways of breeding new strains of plants that are faster and less expensive than traditional methods. Among these are transferring a gene trait via a soilborne bacterium, *Agrobacterium tumefaciens*, or by using viruses and viroids as vectors to introduce desired genomes into a plant cell. The value of using such genetic carriers is that of transforming higher plants in a planned direction. However, for now, the technique has potential but not practice, due to a still limited understanding of plant genetics. Thus, *Agrobacterium tumefaciens* injects its own DNA into plant cells at wound sites, resulting in cancerous growth and the production of a crown gall. What is not known is the structure of the genetic sequence for tumor induction, including the signals responsible for integrating and expressing that sequence in plant cells. Even without knowledge of these signals, DNA foreign both to the plant cell and to the bacterium has been inserted into plants, along with the tumor-inducing sequence. But such DNA has not been expressed. Further work surely will lead to the ability to use *Agrobacterium*, or other carriers, to insert desirable genes into plants.

The satisfactory culmination of gene transfer requires the ability to regenerate whole plants from single and selected cells or from protoplasts, a process called *totipotency*. In principle, a single plant protoplast can be transformed with foreign DNA and a transformed whole plant then generated. However, as indicated above, deliberate transformation of selected cells is still more potential than practical. And the generation of whole plants from a single cell or protoplast is more of an empirical art than closely reasoned science. Moreover, while some plants, such as potato, alfalfa, and carrot, can be generated from individual cells, others, such as corn, wheat, and soybeans, cannot. Why some plants are experimentally totipotent and others are not eludes present understanding.

However, enough is becoming known of the details of the plant genome that we can begin to understand how viruses and bacteria manipulate the control of gene expression in the plant for their own benefit. And, we can carry out some simple genetic manipulations. This manipulative ability will enable us to learn how the plant controls the expression of its genes in normal growth and development and in response to various injuries.

The refinement of these techniques and the rapidly increasing knowledge of how genes are transferred have created a great sense of excitement and new possibilities among plant biologists. An increased understanding of how plants control gene expression should help us to continue improving crop plants to fit them to our needs more closely than ever before.

Cell Receptors for Hormones and Neurotransmitters

The cells of an animal or a plant must function in an integrated manner for that organism to survive and reproduce. In turn, integration depends upon the ability of the cells to recognize and respond to such chemical signals as hormones and neurotransmitters. That recognition and response relies on special molecules or structures in cells, called receptors. As has been the case for molecular genetics, the last decade has been marked by a rapidly growing understanding of what receptors do and how they work.

Hormones and neurotransmitters coordinate the development and functions of the many specialized tissues of higher animal organisms by acting as chemical messengers that convey information between cells. These messengers bring about their biological effects by first combining with specific receptor molecules in responsive cells.

All known neurotransmitter and hormone receptors are proteins. It is the attachment of the messenger to a particular receptor protein that provides the actual signal to a responsive cell. In some cases, the same hormone may combine with more than one type of receptor and therefore can send cells different messages. If the appropriate receptor cell is lacking or defective, then the physiological responses to a hormone or neurotransmitter will be absent or attenuated.

Receptor studies have increasingly important medical applications. Testing the ability of new chemical substances to bind to specific receptors provides rapid and inexpensive screens for drugs that may potentially mimic or antagonize the actions of various hormones or neurotransmitters in living organisms. This may aid the development of therapeutically valuable drugs. Indeed, receptor studies aided the development of certain antipsychotic drugs and of propranolol for the effective treatment of hypertension.

Since it is a combination of a messenger and its specific receptor that actually cues a cell's behavior, it is conceivable that certain diseases in which the symptoms resemble the result of too little or too much of a given hormone or neurotransmitter might actually reflect abnormal numbers or functions of a particular receptor, perhaps for genetic or other reasons. Certain rather uncommon forms of diabetes do, in fact, seem to be associated with defective insulin receptors rather than abnormal levels of circulating insulin. Comparably, the neurological disease myasthenia gravis is apparently caused by the blockade of one class of neurotransmitter receptors by antibodies against these receptors manufactured by the patient's own immune system.

Genetically determined defects in receptors for male sex steroid hormones are associated with some rare disorders in which the patients have a normal male complement of sex chromosomes and develop testicles that readily produce testosterone, yet often develop other bodily sex characteristics that are female in appearance. Studies of these diseases, and of comparable disturbances of male sex development in animals, have revolutionized our understanding of the mechanisms by which male or female reproductive organs are formed in the embryo and develop further after birth and at puberty. Tests based on estrogen receptor determinations are of value in selecting alternative treatments for cancer of the human mammary gland. Research on the relationship of receptors to those cancers responsive to several other types of hormones is now under way at many institutions.

Such studies on hormone and neurotransmitter receptors in relation to the cause and treatment of human diseases are still very much in their infancy. There can be no doubt that this important new field will develop tremendously over the coming decade.

Neurobiology

The nerve cells of the brain communicate using chemical and electrical signals to process information through the complex pathways by which we act and think. The search for ways to understand the physical basis of behavior and mind is difficult and only incrementally successful. A spectrum of implications is emerging from research on the brain. These include improved understanding of psychiatric and neurological diseases, the physical basis of learning, and the effects of aging. Through the use of animals in research, we now have a better understanding of the behavioral abnormalities underlying certain aspects of depression and anxiety.

The fundamental scientific challenge for neurobiology is to discover how the biological mechanisms of the brain give rise to complex adaptive behaviors and associated mental processes and how these processes can become disordered in disease states. While the relationship between mind and body remains, in some respects, as mysterious today as it was to the ancient philosophers, there has been an explosive growth in recent years of knowledge about how the brain is organized anatomically and how it functions at the biophysical, biochemical, and physiological levels to produce behavior. This research is producing new insights as to how the brain accomplishes such complex mental acts as learning, remembering, perceiving, and understanding, and how these functions become disturbed in mental illness. Indeed, the realization that mental and behavioral disorders can be linked to abnormalities in brain chemistry and physiology has led researchers to investigate biologically based therapies for a wide range of neurological, psychiatric, communicative, and cognitive disorders.

In the past few years, the principles that guide the development of the embryonic nervous system into the adult brain have been defined more precisely. Substances have been isolated that promote the growth of nerve cells and their interconnections. The transplanting of viable nervous tissue from one brain to another has been realized.

National Institutes of Health

Researchers are using a technique called CARTOS (computer-aided reconstruction and tracing of serial sections) to help them model the brain. This computer reconstruction shows the fore-brain, eyes, and optic nerves of a newborn zebra fish.

It is likely that these discoveries will make it possible to compensate for many types of brain injury as well as for the developmental disorders that result in impaired behavioral functions. At the far end of the lifespan, specific changes in the structure and chemistry of nerve cells have been linked with the profound intellectual decline (dementia) that occurs in some persons as they grow older. While we are a long way from being able to intervene in the normal aging of the nervous system, there are good prospects for developing effective treatments for some forms of dementia over the next few years.

The chemical mechanisms by which nerve cells communicate are now understood in considerable detail, as are the modes of action of many neurotransmitter substances. This knowledge should result in more effective drug therapies for the many neurological and psychiatric disorders associated with abnormalities in specific neurotransmitter systems. The recent discovery of naturally occurring peptide neurotransmitters that exert the same effect on the brain as the opiate drugs (for example, morphine) has substantially altered current conceptions of the neural basis for pain perception. Research on these endorphin neurotransmitters and on the neurophysiology of the pathways that mediate pain is leading to improved methods for alleviating chronic pain associated with injury or disease.

The brain's ability to learn and remember underlies the development of both normal and abnormal behavior, since the majority of our intellectual and emotional characteristics are either learned or modified through life experience. Experiments on simple forms of learning in animals have revealed both the neural pathways involved and the cellular changes that make behavior modification possible. Investigations with human subjects have identified the brain structures critical for the formation of new classes of memories and learned skills. While there are still many gaps in our knowledge, these lines of research are converging toward a comprehensive understanding of how memories are stored and retrieved in the brain, and how they come to be expressed in thought and action.

New methods have been developed toward visualizing the intricate pattern of electrical and metabolic activities that forms a basis for higher cognitive functions. Complex mental acts such as speaking, reading, and paying attention have been associated with characteristic patterns of energy metabolism and neural-electric activity in the brain that can be detected through the intact scalp. The use of these mapping techniques in conjunction with precise behavioral measurements should lead to new conceptual advances in understanding how mental processes are orchestrated in the myriad pathways of the brain.

Implications for Health Care

Trends and developments in the biological sciences, some of which are reviewed in these eight topical summaries, have significant implications for health care in the United States.

The Nation is likely to continue to face escalating costs of treating the chronic diseases that increasingly incapacitate and kill Americans: heart diseases, cancers, arthritis and related disorders, metabolic diseases, and a wide and complex array of psychiatric and neurological diseases. These diseases—successors to such acute illnesses as pneumonia, tuberculosis, infantile diarrhea, syphilis, and typhoid fever as leading killers—have causes that remain unknown and develop in patterns not sharp enough to enable invariably successful intervention. Much of the care applied to them is simply supportive or symptomatic—costly "halfway technologies."

Yet, as several of the topical summaries of this chapter suggest, we now have new windows into many of these disorders. The unraveling of how messages are transmitted from outside to inside the cell, and what happens when that communication system is disrupted, is in turn clarifying the nature of an increasing number of diseases—hormonal illnesses, such as diabetes, and neurological diseases, such as myasthenia gravis.

Receptors, by which cells receive messages, are constructed under genetic direction, as are the molecules that direct the synthesis, storage, and secretions of the neurotransmitters and hormones. Therefore, whatever affects genetic function radiates to receptor structure and function. And this coupling of molecular and receptor biology in turn ties into work on neurological structure, physiology, chemistry, and psychobiology.

New technologies have transformed clinical practices. For example, in gynecological surgery, the carbon dioxide laser has made an enormous impact by changing surgical procedures that once required hospitalization into procedures that can be done during office or outpatient visits, with substantial savings in cost, time, and hospital resources, as well as reduced patient trauma. The same is true for the use of lasers for eye surgery.

There is, at the moment, a virtual explosion of biological knowledge. This may indeed be the era of biology, an era in which the innovative use of instrumentation produced from the contributions of the physical sciences—lasers, large-scale integrated circuits, and computers, for example—is emerging with fundamental insights into the nature of the living cell.

The direct implication is not that chronic diseases will fade. In the next several years, however, there may emerge wholly new approaches to prevention and treatment of these diseases—techniques that are not merely ameliorative but that rest upon penetration of the fundamental causes of the diseases. These techniques will be highly specific, quite complex, and require fundamental understanding for effective application.

Implications for the Organization and Conduct of R&D

Several possible broad implications for the organization and conduct of research and development and for the integration of those activities into society emerge from this topical review of trends and developments in selected science and engineering fields.

The Emergence of Research-Based Technologies

The rapidity of scientific and technological advances links directly to the emergence of new research-based technologies. These are technologies that would not exist without basic research, for which the role of basic research was not to improve but to germinate. Thus, as implied earlier, molecular beam epitaxy could not and did not exist before the perfection of new methods and insights in surface science. The remaining years of the 1980s will see more advanced technologies created by research. There are hints of these in this chapter—totally new approaches to treating major mental illnesses relying on a molecular understanding of how the brain functions; new sensory devices for the handicapped; new tactics for clinical diagnosis and surgery enabled by new lasers; new agricultural insights flowing from a deeper understanding of plant biology; and much more versatile industrial robots.

The implication is that, more than ever, basic science will be vital to technological advance and, in turn, to better productivity and enhanced economic growth and social progress. Although basic science is not inexpensive, it still is the least costly component of technological innovation. And its value in the years ahead will be multiplied as the national economy, both its manufacturing and its service sectors, is suffused by advanced technologies.

The Pace of Technological Innovation

A 1960s study found an average lag of 30 years between basic research and technological application. Today, the lag is much shorter, as evidenced by the accelerating creation and use of new lasers, by the quick exploitation of such new scientific insights as recombinant DNA methods, by the discovery of brain peptides, or by the creation of polymetallic cluster catalysts out of surface studies.

The more rapid pace is also evident in the emergence, within the very recent past, of a new biotechnology industry principally relying on work done in the past 10 years. Similarly, the intense industrial development of very large scale integrated circuits depends on a knitting of fundamental work done almost in parallel, embracing materials and solid-state science, a host of new spectroscopies, and atomic and molecular physics. The character of industrial research and development in many instances has been altered by fundamental work, much of it again within the past 10 years. For example, the pharmaceutical industry has altered its approaches to designing, creating, and testing new drugs, governed by the new understanding provided by receptor biology of how signals enter and change the behavior of cells.

The implication is that we are now in an era of quickening scientific and technological change and that the two intertwine ever more closely. Opportunities are coming so fast, and competition for markets for advanced technologies is becoming so intense, that success will depend directly on the ability to create and then quickly to exploit the new knowledge.

In an era of such rapid transformation, the structures for basic research and technological development must be dynamic and must be constantly freshened by the infusion of new and highly trained scientists and engineers, by adequate instrumentation, and by rapid communication of fundamental knowledge, as discussed below.

The Importance of Improving Scientific and Technical Communications

The intensifying pace of scientific advance and the increasing importance of basic research in gestating new technologies imply that the American research system must exploit to the fullest the new communication modes now becoming available. Possible new approaches to improving the communication of scientific and technical results include electronic networks for the rapid transmittal of "mail" and data, growing numbers and capacities of electronic data bases, and electronic forms of rapid publication.

The importance of these emerging communication modes to the progress of science and technology is intensified by the increasingly interdisciplinary nature of many fields of science and technology. For example, progress in two fields summarized in this chapter—neurobiology and surface science—is generically dependent on scientists and engineers from diverse fields interacting rapidly and extensively. Progress in these fields—and, increasingly, maintenance of excellence in many fields of science and engineering—will depend on sophisticated use of the new communication modes.

It is ironic that although American scientists and engineers pioneer in the development and use of the latest and most sophisticated instrumentation in their experimental work, the instruments they use to exchange information have changed relatively little. With few exceptions, scientists still rely on two major and somewhat traditional forms of information exchange: face-to-face communication (by traveling to national or international meetings) and reading scientific publications (either directly in the office or library, or by requesting the author to send a reprint). Depending upon the scientific locale and the size of the network in which the scientist is involved, the standard sources of information may be supplemented by seminars, letter writing, and the telephone. However, for the most part, the information being exchanged may be anywhere from months to years behind the actual state of the experimental program at the bench or the conceptual progress shared between leading members of a field.

Such continued reliance upon printed statements of progress or upon face-to-face contacts is an unnecessary impediment to the progress of science and technology and to its communication. New methods, based upon advances in electronic communications, could improve substantially the communication of science. Nevertheless, a skeptic might argue that these advances in communication (perhaps viewed as only modest improvements on the telephone) will only contribute to information overload. A major need now is to encourage a comparable advance in "smart" computer terminals through the use of programs that can digest, scan, and analyze the scientific flow of electronically stored information, filter it for each reader's self-defined profile of interests, and then condense the data. The discussion of robots has indicated the importance of the interactions between hardware and software developments for progress in automated machine capabilities. Similar extensive research and development in computer language and artificial intelligence will be required to realize the full scientific and social potential of the new electronic media.

The Dissolution of Disciplinary Boundaries

Finally, traditional disciplinary boundaries are dissolving between the traditional fields of science and between science and technology. As examples of this trend, consider, as described in this chapter, how solid-state physics has merged with materials science and with chemical engineering and computer science to produce new catalysts and microelectronic fabrication methods; how optics, solid-state physics, and cellular biology have merged in the creation of flow cytometry for analyzing cell components; how robotics and neurobiology merge in their analysis of vision. Fundamental studies of how a smoothly flowing fluid becomes a turbulent one devolve into work in mathematics, in physiology, in the dynamics of the atmosphere, and in galactic structure. The search to uncover the structure of cell receptors needs the recombinant DNA techniques of molecular biology. And fundamental work in receptor biology has in turn sparked the discovery of peptide receptors governing neurological events.

The discussion of surface science also makes the point that science and technology increasingly are synergistically coupled. Surface science, in its modern form, is a product of several technologies that provided high-vacuum instrumentation and tools for measuring surface events and structure. In turn, the science has created a potential new technology, molecular beam epitaxy, for building semiconducting layers 100 atoms thick, varying by one or two atoms. Molecular beam epitaxy will surely create a new generation of electronic and electro-optic devices. That advance occurred in the past 15 years, and the rapidity of the progress and application is due to the close coupling of fundamental scientific work with the development and production components of technological innovation.

In fact, instrumentation increasingly knits together science and technology—nuclear magnetic resonance, scanning electron microscopes, a panoply of lasers, new sources of synchrotron radiation, and a vast array of other tools are indispensable to the advances and opportunities recounted in this chapter.

A significant policy implication of these dissolving boundaries concerns the question of which areas of science should have priority support. This becomes more difficult to answer, since advances of knowledge in one field may have a significant effect on understanding phenomena in a quite different field, and the major contributions to instrumentation, technique, and methodology can flow across disciplinary boundaries.

Chapter III

Federal Research and Development Programs

Agricultural Research Service

This chapter summarizes the major science and technology accomplishments in 1982 in a broad range of Federal research and development programs. Although 22 executive branch agencies contributed to it, this chapter does not cover all science and technology programs of the Federal Government or accomplishments of the non-Federal sectors. It only highlights the significant results that have been achieved in 1982 in federally supported science and technology programs at the agency level and points to significant developments likely to occur in the coming year.

The areas discussed in this section are:

- *National Security*
- *Space*
- *Health*
- *Energy*
- *Natural Resources*
- *Environment*
- *Transportation*
- *Agriculture*
- *International Cooperation*

A scientist at one of USDA's research labs examines rice plants grown from tissue-cultured plantlets. These plants, here shown growing in a greenhouse, produce grain that has 10 percent more protein than most rice.

One of the principal objectives of the Reagan Administration is to restore the Nation's defense capabilities, and science and technology are regarded as fundamental to that objective. There are two essential functions served by national security-related research and development. The first is to maintain superior science and technology, both as a source of future procurements and as a hedge against adverse technological surprise. Second, the technology must be applied more effectively, which means phasing it into use more rapidly and efficiently.

A number of significant accomplishments were reported during 1982 in national security research and development programs:

- Several new preventative drugs and vaccines were developed, including a meningitis vaccine, an adenovirus vaccine, and mefloquine, an antimalarial drug;
- A nondestructive test to locate previously undetectable helicopter rotor blade flaws was developed, improving the safety and mission effectiveness of helicopters;
- In laminar flow technology, major drag reductions were achieved in the laboratory using heated boundary layers, suction, and polymer ejection;
- A unique material process was discovered that produces a potentially superior transparent missile dome material with improved rain erosion resistance, improved thermal shock resistance, and reduced thermal emissions; and
- Advances in optical sciences and electronics have led to a new kind of hydroplane detector based on optical fibers. The new detector shows potential for submarine detection, operating at low frequencies with very low noise levels and very high sensitivity.

The national security R&D programs are made up of hundreds of projects, some supporting long-range research to provide technological progress on an evolutionary basis, while others have potential for revolutionary improvements in future military capabilities. For example, in the latter case, some projects will provide bases for identifying and advancing key technologies in response to President Reagan's call in March 1983 for a bold initiative in strategic defense. The section that follows highlights initiatives and recent accomplishments in all areas relevant to national security.

Computers

Current national security requirements include the ability to compute accurately the mathematical models that arise in oceanographic and weather forecasting, to perform three-dimensional calculations of flows about aircraft and ships needed for optimal vehicle design, and to extract information from the growing data sets collected by advanced sensors. In addition, applications of the newer fields of artificial intelligence and robotics for "smart" weapons, intelligence analysis, decision aiding, and automated and computer-assisted training, production, and maintenance raise new challenges requiring interactive efforts in the development of computer algorithms, software, and architectures (system organization).

Large-Scale Computation

New commercially developed "supercomputers" offer the ability to handle significantly increased computation at much greater speed. These machines use parallel and vector architectures that allow many computations to take place simultaneously rather than sequentially, thus dramatically increasing the effective speed of computation. To exploit these new computers, however, requires a rethinking of the algorithms used, since most available codes were designed for sequential machines. New coding methods have been integrated into an electronic circuit analysis program, resulting in a speedup of 6:1 over the original (scalar) version of the code for a "small" digital circuit. Speed increases of 10:1 or more are expected for larger circuits.

Highly Parallel Architecture

Modern microelectronics technology is leading to inexpensive logic components that make decisions, perform arithmetic, and store data. This will allow future computers to be made up of thousands of small, inexpensive processors. By having these processors simultaneously attack small segments of large problems, a match can be made between algorithms (recipes for solving problems) and computer architectures (the structuring of the inexpensive processors into a total computer system) so that currently intractable problems can be solved. Research is being conducted on computer-based design aids to help deal with the new highly parallel machines, on developing a better understanding of the strengths and weaknesses of various parallel designs, and on new fault-tolerance principles to make the new computers dependable.

Computer-Aided Instruction

Computer-aided instruction is extremely valuable in the military, where training represents a significant budget item and there is always demand for well-trained technicians and maintenance personnel. For computer-assisted instruction to reach its full potential, however, systems are required that can adjust to the knowledge base, learning strategies, and current skills of individual students. The Department of Defense (DOD) has now developed a system that monitors the current status of the student's learning, compares this with an ideal model, determines the discrepancies between the two, and provides the student with examples, hints, analogies, and other aids to minimize the discrepancy. This research has provided the knowledge base upon which to launch a fairly intensive applied research program in intelligent computer adaptive instruction.

Command, Control, and Communications

The purpose of the command, control, and communications (C^3) program is to develop advanced communications technology and system architectures to improve the Nation's ability to control its fighting forces around the world.

Computer-Controlled Communications Technology

The R&D in tactical computers and systems is focused on making the systems more survivable through the use of "standardized" computers and peripherals that are interchangeable, thus allowing the replacement of any faulty modules on critical systems that must be maintained during battle conditions. To this end, improvements in microelectronics device technology, hierarchical structures, and fault-tolerant hardware are under way.

Communications Networks

In 1982, a research program was initiated to enhance the survivability of the battlefield command and control system by dispersing command post elements. Emerging communications network technologies will provide real-time video, voice, graphic, and digital data communications among cells. Distributed processing and distributed command post techniques not only will improve C^3 survivability, but will also enhance command post operations through the use of automatic internetworking.

New millimeter wave radio technology combines the covertness of cable communications with the bandwidth of traditional radio communications and thus enhances the survivability of tactical radio communications on the modern battlefield. The millimeter wave radio will provide wireless local distribution, command post remote communications, vehicle-to-vehicle communications, and cable replacement capability.

Electronics

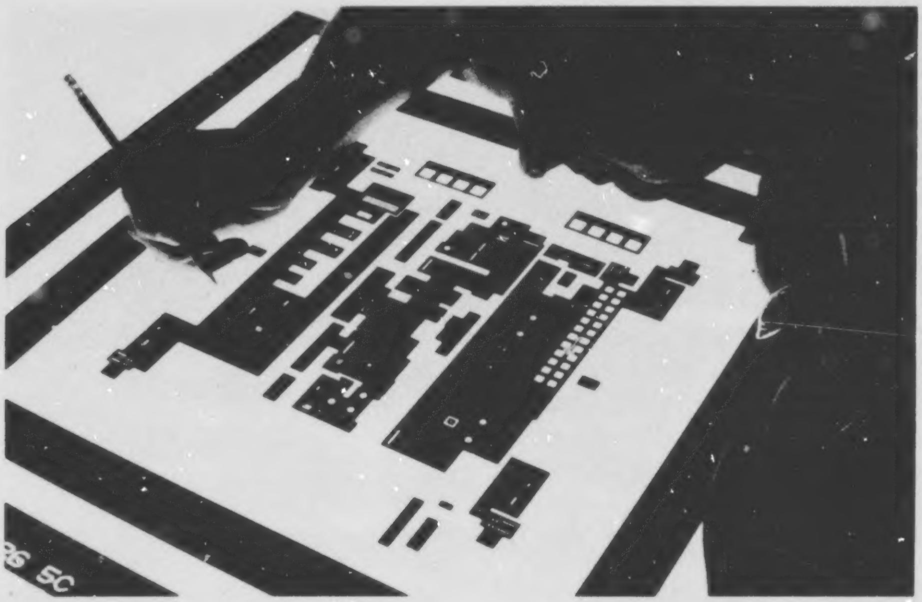
In the past, the ability to win wars was based on the motivation of the populace and industry's ability to respond. Advances in science and technology have drastically reduced the time that nations have to respond to acts of war to the extent that victory is now dependent on technological preparedness. Reliable and sophisticated electronic systems improve the effectiveness of modern weapons systems and provide commanders with accurate, current information so that decisions can be made and communicated immediately to their forces.

Integrated Circuits

The capability to incorporate Very Large Scale Integration (VLSI) in military systems is highly dependent on automation at all levels of design, including process, circuit logic, and development of system simulation and design aids. Research addresses problems inherent in reduced geometries and greater density of integrated circuits (IC). Two-dimensional modeling to account for complex interactions during processing of ultrasmall geometry devices, faster software to obtain simulation in reasonable time, automated testing, and improved algorithms for determining the location and connections among elements are some of the critical issues. The ultimate goal is to perform all aspects of design and manufacturing using automated systems with minimal man-machine interaction, allowing the production of certain devices that would otherwise not be possible.

Physical Electronics, Electronic Materials, and Devices

Physical electronics research provides basic understanding of the electronic, optical, and magnetic properties of materials, including the generation, transport, and modulation of charge carriers. Advances are being made in the following areas: detection of infrared radiation (heat) for surveillance and target identification using new electronic materials such as mercury cadmium telluride incorporated in focal plane arrays; new types of lasers promising high power output from devices small enough to be fielded; acoustic-optic signal processors for spectrum analysis, secure communications, and quiet radar in the adverse electromagnetic environment of the battlefield; and planar-doped barriers, which enable the electrical characteristics of a semiconductor device to be tailored to system requirements for incorporation in a variety of solid-state devices for secure



Department of Defense

A greatly enlarged blueprint of an integrated circuit is being examined.

communications, target acquisition, and fire control.

Materials

Advanced materials research and development are required for new defense systems. Pioneering and revolutionary materials and structures technology programs are providing the basis for significant advances in a wide variety of structures and components, such as aircraft, helicopters, satellites, missiles, communications systems, sensor devices, land vehicles, and ships. These R&D programs emphasize substantial improvements in performance, reliability, fabrication capabilities, initial manufacturing, and life-cycle costs.

Biomolecular Engineering

Rapid advances in biotechnology allow production of novel cells that can be directly exploited to produce new, improved, or otherwise useful materials with a variety of mechanical, electrical, optical, thermal, structural, and chemical properties. Current research is aimed at developing selective, ultrasensitive sensors applicable to distinct strategic and tactical DOD problems. Two families of devices are being developed. The first exercises "single-molecule" sensitivity, extraordinary specificity, and may be embodied in self-contained systems operating unattended for several months. The second focuses on ultrasmall, inexpensive, sensitive, specific devices offering real-time response.

A new program capitalizes on recent advances in molecular biology including genetic engineering, monoclonal antibodies, enzyme immobilization, the molecular basis of marine fouling, and the synthesis of materials with controlled molecular structures. The multidisciplinary effort is dedicated to providing new approaches to defense materials requirements. Among these are improved adhesives for composites; methods for corrosion control; new fuels, lubricants, and propellants; improved techniques for surface modification of various optical and electronic components; and miniaturized electronic devices.

Optical and Electrical Ceramics

Ceramic materials are essential to such diverse electronic systems as missile domes, dielectric components, and sonar devices. An important example is the improved reliability of multilayer capacitors critical to the performance of missile guidance systems. Research includes fundamental studies of the failure mechanisms in these capacitors and the relation of the failure modes to the various steps in processing and fabrication. Another new effort is the development of a zinc-alumina-germanate glass for missile domes. This material can be cast directly into a full-scale, multimode (infrared, ultraviolet, visible) dome.

Composites

Composite materials are tailored structures with at least two major component phases, one of which is generally a high-strength fiber to provide reinforcement, and the other provides the matrix base that encases the reinforcing fibers. Current DOD attention is focusing on carbon/carbon, ceramic/ceramic, and metal/matrix composites.

Ceramic/ceramic composite materials are the newest composites being explored. They consist of ceramic fibers in glass/ceramic matrices or ceramic particulates in a second ceramic phase. These materials have demonstrated fracture toughness approaching that of metals, high reproducible strength, density one-third that of superalloys, very low tendency to change shape under constant load, and high oxidation resistance. They can provide components for many advanced defense systems, including high-efficiency, lightweight turbine engines, new missile radomes, long-life reliable submarine shaft seals, and lightweight armor.

Rapid Solidification Technology

Rapid solidification technology (RST) is being used to produce a wide range of high-performance metals having new or improved properties. In RST, a liquid metal is cooled at very high rates to produce unique structures or microstructures. For suitable alloy compositions. RST techniques have produced amorphous (i.e., noncrystalline) metals, some of which exhibit very high magnetoelastic coupling and thus can be used to produce superior sensors. The amorphous metals also exhibit very "soft" magnetic behavior, making them useful in a range of electronic devices.

Currently, amorphous metal alloys are being evaluated for incorporation into such devices as transducers for hydrophones and pressure sensors for mines. Major energy savings are possible when amorphous metal cores are used in distribution transformers of the electric power network. In addition, many RST-produced alloys are low in content of such critical materials as cobalt and chromium.

Metal Flow Analysis

A program to develop methodologies for metal flow analysis in forgings has been initiated. Its goal is airframe and engine components with optimum mechanical metallurgical properties. An advanced finite element program for analyzing forging and forming operations has been developed, and this analysis has been used to model microstructure and properties in the dual-property compressor disk, spiral bevel gears, artillery shells, and stretch-forming sheet metal. Manufacturing technology engineers and industrial forging and aerospace firms are considering the method as a tool for design and manufacture of complex forgings. The activity is a major breakthrough in processing science that cuts down leadtimes for components, reduces fabrication costs, and increases durability of products through production components of controlled and optimized properties.

Manufacturing Technology

DOD must ensure the most effective use of its resources. By continually providing new or improved production processes, equipment, and methods, DOD can reduce production costs, shorten production leadtime, improve product quality and reliability, and provide alternate production sources. Substantial benefits also are derived from improved production safety and conservation of critical materials.

Systems Automation and Evaluation

Many techniques are being incorporated into production processes to provide optimum control and precision. Research on intelligent robotics is focused on developing efficient and flexible production centers for automated assembly and on designing tests to be performed completely by robots that can be easily and rapidly reconfigured by humans. Companion efforts address intelligence techniques to allow cooperation between autonomous robots. Optical techniques for automated measurement of part dimensions and assembly tolerances are under evaluation. Noncontacting or minimal contacting methods of nondestructive evaluation (NDE) that operate in near real time are being developed for production process control. Manufacturing information systems to determine and characterize the information flow necessary for optimizing the entire manufacturing cycle are being investigated.

Computer-Aided Design

Computer-aided and computer-controlled manufacturing processes have also been developed, including ultraprecision machining, computer-controlled welding, electroforming, and surface treatment. There is an initiative to automate the exchange of design information among geographically dispersed design and production facilities having disparate computer-aided design and computer-aided manufacturing equipment.

Precision Engineering

Aimed toward enhancing the Nation's defense capabilities in metrology, processing, and machinery, a new research program has been initiated in precision engineering.

In close concert with industry and Government, a number of university-based centers will be working on a wide spectrum of challenging problems, including the science of part specification for precision, sensing technologies and adaptive techniques, generic control problems of precision production processes, and precision problems of robot sensing for autonomous operation. Precision engineering underlies improvements in productivity, in product advancement, and in technological innovation necessary for national defense.

Air and Space Transportation

Major research emphasis has been on increasing the energy efficiency of flight vehicles. Aircraft able to operate at low speeds, possibly in the vertical mode, with adequate control and without serious compromise in overall mission effectiveness are also being developed. Emphasis in space transportation is on spacecraft power and propulsion technologies for more efficient orbit transfer and on increased energy efficiency of space vehicle electrical power sources. Programs in spacecraft structures and materials are aimed at developing more stable large-scale spacecraft with extended life.

Aeronautics

Turboprop research is directed at a 15 to 20 percent reduction in fuel consumption compared with equally advanced turbofan engines. Three important steps have been completed in the development of advanced turboprops to power future military or civil transport/patrol aircraft. Flight tests of a small-scale propeller established that near-field propeller noise was less than predicted; cabin noise attenuation using new cabin wall structural concepts achieved or bettered the theoretically predicted improvements; and subscale model wind-tunnel tests showed that low-drag propulsion installations are possible.

A hypersonic ramjet engine for missiles that uses a two-stage combustor to achieve high propulsion efficiency with conventional hydrocarbon fuels is being developed. The engine uses a subsonic combustor in the aft end of the air inlet that acts as a generator of hot, fuel-rich gas, which is the fuel source for the main, dual-mode (subsonic or supersonic) combustor. Proof-of-concept for the system has been demonstrated. The gas generator (subsonic combustor) has been operated stably and, with the complete combustor (gas generator in tandem with the main dual-mode combustor), has demonstrated high combustion efficiencies when operating in subsonic or supersonic combustion modes. Resulting increases in range capability and trajectory flexibility will allow missiles to intercept targets at all altitudes.

The search for new methods to reduce turbulent friction drag saw intense activity during the past year. Certain types of surface modifications, such as longitudinal v-shaped grooves known as "riblets," have lowered skin friction through an accompanying reduction in the turbulent burst intensity. Another boundary modification technique involving a small-amplitude, asymmetric waviness of the surface has significantly reduced friction drag without significant penalty from increased pressure drag. Large-eddy breakup devices (LEBU), consisting of arrays of thin plates suspended in the boundary layer interior, have yielded dramatic reductions in the turbulent shear stresses in laboratory experiments.

Space Transportation

The Dynamic, Acoustic, and Thermal Environment experiment, flown in the bay of the Space Shuttle Columbia, was jointly funded by the National Aeronautics and Space Administration (NASA) and the Air Force. Data indicate that the payload bay environment is more benign than anticipated, and additional measurement packages are planned.

An ion auxiliary propulsion system is ready for integration into an Air Force spacecraft scheduled for launch in 1983. It will verify, in space, the functional operation and life of a 1 millipound thruster and obtain in-situ measurements of efflux particles and electric fields. The thruster system is suitable for north-south stationkeeping of geosynchronous military and civilian communications satellites.

Construction of the National Transonic Facility (NTF) is complete, and operation began in the fall of 1982. This facility provides the United States with the capability for testing full-scale Reynolds numbers in a critical flight regime for current and planned transport and high-performance aerospace vehicles. An important benefit of the facility is its ability to allow independent investigations into the effects of compressibility, viscosity, and aeroelasticity. The NTF will impose severe requirements on models, instrumentation, and model support systems; therefore, an extensive research program is providing the necessary ancillary technology. The NTF was designated from the outset to be a national facility, satisfying the research and development needs of NASA, DOD, industry, and universities. There is considerable interest in the NTF in the Air Force, and a number of industrial firms have scheduled their program models for testing.

Lasers

The DOD Directed Energy Program, with elements in each of the Services and the Defense Advanced Research Projects Agency, continues to explore the feasibility of using high-energy lasers in a variety of military applications, ranging from forward area combat on the battlefield to strategic missions.

A report to Congress on Space Laser Weapons was prepared and submitted in May 1981, with a recommendation that the program be augmented by $50 million per year. A detailed program plan was sent to Congress on June 21, 1982, envisioning a decision in the latter part of this decade on whether to proceed with an on-orbit demonstration prototype. That decision relies on resolving the uncertainties in technology and ultimate utility of space-based laser weapons. An aggressive research program is being pursued to reduce these uncertainties.

Environmental Sciences

Environmental conditions can be critical in deciding the outcome of military conflict. Accordingly, the Department of Defense sponsors extensive research in oceanography, meteorology, terrestrial science, and space science.

Oceanography

Two key oceanographic research projects are ocean acoustic tomography and remote sensing by satellite. Acoustic tomography applies the same principles as the medical CAT scan, but using sound waves rather than X-rays, to measure physical properties of the ocean in three dimensions over large areas and for extended periods. Satellite technology, while well-advanced in its application to meteorology and other disciplines, remains probably 5 to 10 years from becoming fully exploited and established in oceanography. Improved sensors, especially microwave systems able to penetrate through atmospheric aerosols, and new capabilities for recording and processing the resultant voluminous data will be critical problems.

Meteorology

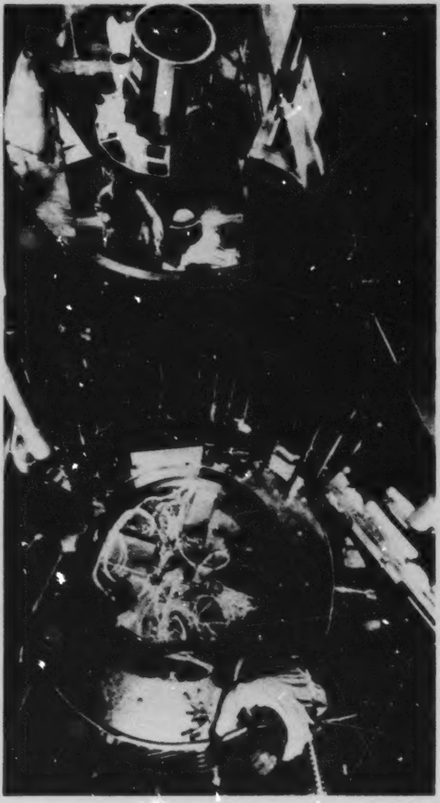
Of several research thrusts that address meteorological problems, mesoscale modeling and electromagnetic (EM) transmission studies are two examples. Mesoscale modeling of the atmosphere, while superficially similar to synoptic (large-scale) modeling, represents a new order of technical difficulty—and potential payoff. Accurate observational and advanced computational systems, conceptually definable today but far from the engineering development stage, will be needed to produce reliable definition and prediction of local and intense weather events. EM transmission studies similarly are concerned with gaining a better understanding of fine-scale motions and processes. As military applications increase in the millimeter and infrared spectra, the scattering and absorptive effects of snow, clouds, rain, dust, and smoke acquire greater importance.

Terrestrial Science

Terrestrial research addresses long-range problems in land combat, surveillance, navigation, construction, and surveying. Of the leading research efforts, one is in detailed mapping of the earth's magnetic and gravity fields, an essential ingredient in the precise guidance of Intercontinental Ballistic Missiles (ICBMs). Another is in Arctic studies, directed toward understanding the geophysical structure of the region and related interdisciplinary efforts to understand the physical processes by which ocean, ice, and atmosphere interact.

Space Science

While clearly the newest of the environmental domains requiring defense-related research, space is in some ways the fastest growing and the most technology dependent. The development of technologically sophisticated systems for space communication, surveillance, targeting, and weapon deployment may in many cases depend upon space science research achievements. Current studies address physical effects on orbital vehicles, remote sensing technology, ultraviolet light applications including ionospheric mapping and prediction, command and control systems performance prediction, over-the-horizon surveillance and communications, laser and particle beam technologies, and the character of magnetospheric substorms and the space radiation environment.



Department of Defense

Simulating the conditions found in space, this chamber provides a way of testing satellite system components and circuitry which will operate in future defense systems.

On July 4, 1982, President Reagan announced a national space policy that sets the direction for U.S. space efforts for the next decade consistent with the Administration's goals for the Nation. The policy reaffirms the national commitment to explore and use space to support the Nation's well-being. It stresses the importance of space for both civil and national security purposes, the requirement for close coordination between the activities of those two sectors, and the use of the Space Shuttle as the primary space launch system for both.

Some major accomplishments of the space program during 1982 were as follows:

- Issuance of a national space policy that sets the direction for U.S. civil and military space efforts for the next decade;
- Completion of orbital flight testing of the Space Transportation System, followed by the system's first operational flight and first delivery to space of commercial spacecraft;
- First use of two upper stages—the Inertial Upper Stage, which is an upper stage both for the Titan expendable launch vehicle and for the Space Shuttle, and the Shuttle Payload Assist Module (PAM-D); and
- Demonstration in space of electrophoresis, a technique for separating biological materials in a continuous stream, which may be used to produce pharmaceuticals that currently can be made on Earth only in quantities limited to research use.

New developments in space flight, astrophysics, space research and technology, and applications of space technology are described in the following sections.

Space Flight

In accordance with the President's space policy, the Space Shuttle will progressively take over primary responsibility for the launching of U.S. payloads. However, the demand for specialized launch services is expected to be high enough to require continued use of expendable launch vehicles for some payloads for several years.

Space Shuttle

The principal element of the Nation's spaceflight capability, the Space Shuttle, successfully completed its flight-test phase in 1982. Several science and applications experiments were conducted, including one of the ten national winners in the first Shuttle Student Involvememt Project competition sponsored by the National Aeronautics and Space Administration (NASA) and the National Science Teacher's Association to stimulate the study of science and technology in secondary schools. However, the principal purpose of the flights was to investigate the Shuttle's performance.

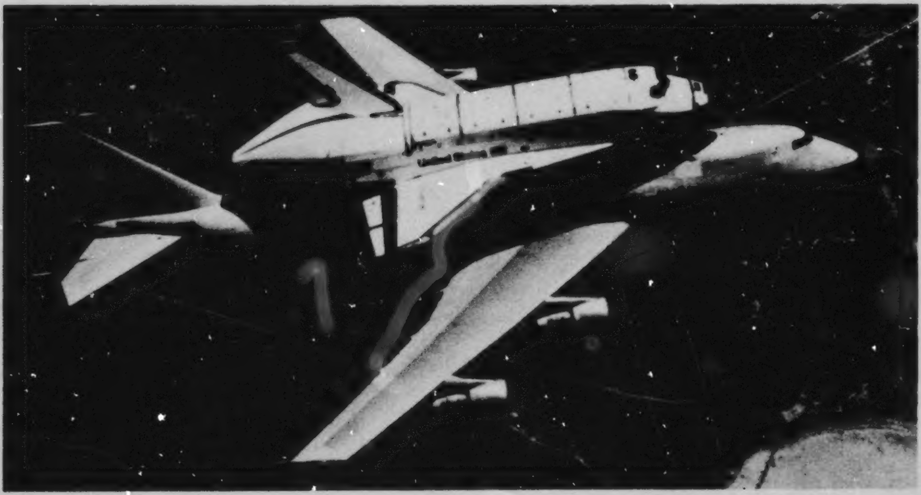
The Shuttle's first operational flight, in November 1982, launched two commercial communications satellites. Part of the European-developed Spacelab was flown in the Shuttle, and progress continued on schedule for the initial launch of Spacelab as a complete Shuttle payload in 1983. With the July 1982 delivery to Kennedy Space Center of the second Shuttle, the buildup of the currently authorized four-Shuttle fleet also continues on schedule.

Expendable Launch Vehicles

In July 1982, a new configuration of the Delta expendable launch vehicle was successfully used to launch Landsat-4 (discussed in the natural resources section of this chapter). The new configuration is able to transport 135 kilograms (300 pounds) more payload to geostationary transfer orbits than former Delta configurations could. That greater capability will significantly increase the Delta's utility for launching communications satellites. Although NASA sponsored and managed the development of the new configuration, industry funded and conducted the development and will recover its costs through appropriate charges to users.

Upper Stages

The Inertial Upper Stage, a two-stage, solid-propellant rocket vehicle designed and de-



National Aeronautics and Space Administration

Challenger, the second Space Shuttle, rides on its 747 carrier aircraft to the Kennedy Space Center prior to its maiden flight.

veloped by the Air Force, will serve as an upper stage for both the Titan expendable launch vehicle and the Space Shuttle. It can deliver payloads weighing as much as 2,290 kilograms (5,000 pounds) to geosynchronous orbit. Its first flight on a Titan was in October 1982, and the first flight aboard the Shuttle is scheduled for 1983. Planned uses for it include the launching of Department of Defense (DOD) satellites from a Titan and from the Shuttle and the launching of the satellites for NASA's Tracking and Data Relay Satellite System from the Shuttle.

Developments to enhance the performance of the Centaur cryogenic-fueled rocket and to adapt it for use as an upper stage for the Shuttle were initiated in 1982. This upper stage is needed for launching heavy payloads to the outer planets on optimum trajectories, and it is also likely to be needed for boosting heavy payloads into geosynchronous orbit for both industry and DOD. Its capability for transferring payloads to geosynchronous orbit should be about 5,910 kilograms (13,000 pounds). First planned uses are for the Centaur Galileo Mission and the International Solar Polar Mission in 1986.

Advanced Developments

Meeting the goals of President Reagan's space policy will require continuing evolvement of the Nation's space-flight capabilities. Several activities in 1982 addressed that need. Systems investigated include free-flying, Shuttle-serviced, low-Earth-orbit, unmanned platforms; satellite servicing systems of interest to both NASA and DOD; unmanned, Shuttle-derived, space transportation systems; upper stages; and a permanent, manned, orbital space station. For the manned space station, concept-evolution studies were completed, and a Space Station Task Force was established to determine suitable missions, requirements, and general architecture.

Origin, Nature, and Evolution of the Universe: Astrophysics

Consistent with the policy to explore space, astrophysics investigations have added to the knowledge about the origin, nature, and evolution of the universe. The two test flights of the Space Shuttle in 1982 included experiments related to the space environment surrounding the Shuttle and the Shuttle's effect on that environment. Other experiments monitored X-rays emitted by solar flares and gathered information on the frequency, mass, and chemistry of micrometeorites.

Analyses of data from currently and recently operating satellites are providing new insights. During 1982, observations made previously by the High-Energy Astronomy Observatories, HEAO-2 and HEAO-3, yielded information important to an understanding of supernova explosions. Supernova remnants are the portions of an exploding supernova that are ejected violently into space and subsequently interact with and heat the interstellar medium. Further information will be provided by the Gamma Ray Observatory, the development contract for which was awarded in December 1982.

Repair in space of the Solar Maximum Mission (SMM) spacecraft was approved in 1982, and preparations for performing the repairs during a Shuttle flight in early 1984 are in process. Meanwhile, SMM instruments still operating are returning exciting data. The radiometer experiment has provided the first definite evidence of changes in the heat output of the Sun and is expected to lead to many studies of the relationship between sunspots and solar heat output. Data from the gamma ray instrument have yielded important discoveries related to solar flares, including the detection of many previously unknown nuclear reactions in the flares and the first observations ever made of solar neutrons.

Development of the Cosmic Background Explorer was initiated in 1982. That spacecraft's mission will be to explore and to study definitively the diffuse radiation of the universe in the wavelength band of 1 micrometer to 13 millimeters, which includes the 3° Kelvin cosmic background radiation thought to be the remnant of the hot Big Bang presumed to have started the expansion of the universe. The infrared band (1 to 300 micrometers) may contain the dominant portion of the universe's energy content, including radiation from primeval galaxies.

Space Research and Technology

NASA and the Air Force cooperate extensively in space research and technology activities using the capabilities of the Space Shuttle. Significant achievements in 1982 included:

- A successful experiment in the Shuttle that provided means to use environmentally sensitive laboratory equipment in the hostile environment of space;
- Development and testing of a stirling-cycle cryogenic cooler with extended lifetime for use in military spacecraft as well as in NASA's Multispectral Linear Array instrument and Gamma Ray Observatory; and
- Improvements in data processing and communication systems—a real-time signal processor that will have a weight and power consumption about a tenth of those of ordinary filter banks was developed, and a simpler and less expensive alternative to the traditional coupled-cavity, high-power traveling wave tube was fabricated and tested for use in space communications.

Applications of Space Technology

NASA, in collaboration with industry and academia, conducted experiments in processing of materials in the low gravity of space. The possibility of electrophoresis, a technique for separating biological materials in a fluid according to their electrical charges, was demonstrated, as was the production of more uniformly sized latex microspheres than can be produced on Earth. The microspheres are used for precision measurement, calibrating optical equipment and electron microscopes, and measuring blood cells.

National Aeronautics and Space Administration

Astronaut Jack R. Lousma works with the electrophoresis equipment on board the Space Shuttle Columbia.

Remote sensing has also benefited from space technology. Land remote sensing has been ongoing, and additional and better data continue to be collected. In 1982, NASA completed a project to convert all the data collected by the Seasat ocean-sensing satellite into geophysical units such as surface temperature, surface wind speed, and wave height. The results demonstrated that radar techniques can be used to obtain global data on ocean conditions, important to the efficient routing of ships and the protection of offshore facilities.

Space research and technology also led to significant applications in other fields, for example, medical devices. In 1982, an implantable artificial sphincter for control of uninary incontinence was successfully tested in animals. It was based on aerospace research in miniaturized fluid control technology. In another example, work on an implantable device for controlled release of medications (described in the *Annual Science and Technology Report to the Congress: 1981*) inspired the development of a programmable medication releasing device for external rather than implantable use; that device is in initial use by diabetics dependent on insulin. A wheelchair for use in aircraft also resulted from NASA's experience.

An ultrasonic tool developed by NASA for measuring the stress on bolts in wind tunnels is now being used in industry. The new tool is extremely accurate, lightweight, portable, and cost-competitive with other available strain monitors. A second version of the tool has been designed for the measurement of stress in the roof bolts of mine tunnels, and the Bureau of Mines will field test the prototype. In addition, NASA and the Bureau of Mines are planning to modify it to measure the stress in the rock surrounding mine tunnels. Other possible uses are measuring stress in metals, detecting contaminants in lubricants and hydraulic fluids, and testing blood and other liquids for the presence of particulates, bubbles, and clots.

Unispace '82

The United States participated with about 100 other countries in the Second United Nations Conference on the Exploration and Peaceful Uses of Outer Space (UNISPACE '82) held August 9 through 21, 1982, in Vienna, Austria. Delegates from the United States were drawn from Congress, Federal agencies, and industry. The conference examined international cooperative activity in space, with particular attention to how space technology contributes to the economic development of the world's poorer countries. The United States proposed that a program of research into Earth's "global habitability" be undertaken. In this proposal, an international cooperative program would conduct coordinated global studies of the atmosphere, the oceans, the land, the land-ocean interface, and the biosphere.

The Reagan Administration's health research policy aims at sustaining the rapid pace of scientific advances in biomedical research through a balanced effort emphasizing public sector support of long-term basic research and private sector application and commercialization of new knowledge and technologies. Its strategy is to make the wisest possible allocation of public funds to assure progress in basic research, clinical investigations, transfer of new knowledge and technologies to industry and to health care settings, and training of the next generation of biomedical scientists.

The *prevention* of illness remains a singularly important element in the Administration's health strategy. Indeed, research related to disease prevention has become a major thrust in Federal health programs. Among notable successes in recent years have been advances in hypertension control, introduction of several new vaccines (including those for German measles, pneumonia, and hepatitis B), and prevention of some birth defects. Progress has also been made in demonstrating linkages between behavior patterns and lifestyle and certain diseases, and in motivating the public to adopt healthier lifestyles.

Recent advances in biomedical science and technology have been striking. They include refinement and application of gene recombination techniques, the production of pure antibodies through hybridoma technology, the isolation of the agents causing hepatitis, increased knowledge of brain structure and function, and the development of new noninvasive diagnostic tools.

In 1982, science continued to capitalize on the vast opportunities afforded by rapidly moving developments in biomedicine:

- Researchers confirmed long-sought links between viruses and cancer that may play a crucial role in prevention and treatment of the disease;
- New techniques in treating heart-attack patients were proved effective, and these techniques are expected to save thousands of lives each year; and
- Dramatic results were reported in laser treatment of degenerative eye disease in the elderly, a major cause of visual disability and blindness in the United States.

Especially exciting studies in basic research yielded and enhanced understanding of growth and development of cells, tissues, and organs; the regulation of gene activity; the evolution of the species; and the basis of certain genetic diseases.

For the immediate future, several high-priority needs and opportunities will occupy the attention of health research: further advances in controlling the Nation's major health problems such as cancer, heart disease, and infectious diseases; confronting the health needs of an aging population; facilitating transfer of biomedical information to health practitioners; and encouraging international cooperation in biomedicine. Advances in each of these areas are briefly surveyed below.

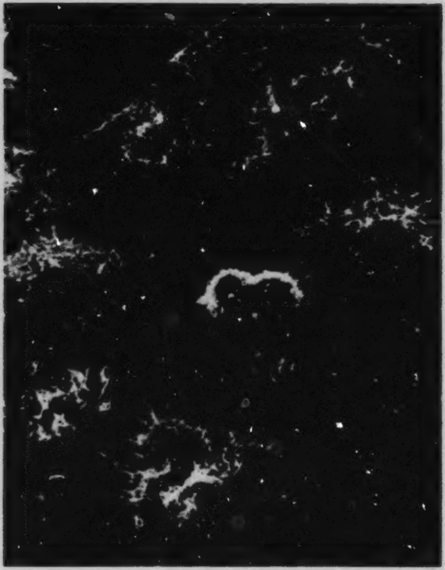
Cancer and Heart Disease

Cancer and heart disease remain the most feared of life-threatening diseases among Americans. Because both are linked in part to environmental and lifestyle factors over which individuals have some control, prevention is viewed as the most promising long-term approach to these diseases. Current research priorities emphasize elucidation of basic disease processes and mechanisms, their prevention or control, improved detection, and diagnosis and treatment of persons with cancer or heart disease.

Cancer

Scientists have recently discovered that certain viruses acquire their ability to cause cancer by capturing genes from normal cells and then "corrupting" them. "Cancer genes" are either subtly different in their DNA structure so that an altered protein is made, or they are deregulated in cancer cells so that too much of a normal protein is produced at the wrong time. Gene changes may therefore be at the core of the cancer process.

Scientists at the National Cancer Institute, within the National Institutes of Health (NIH), recently isolated and characterized the first virus associated with human cancer. This work was confirmed when a similar, if not identical, virus was isolated in Japan, where



National Institutes of Health

The scanning electron micrograph shows cultured HeLa cells derived from cancerous tissue.

the particular form of leukemia associated with the virus is endemic. The identification of a leukemia virus—a landmark discovery—should help scientists devise more effective strategies to prevent this form of cancer.

Meanwhile, investigators supported by the National Institute of Environmental Health Sciences have made substantial progress in assessing environmental factors that may contribute to cancer. For example, a relationship has been shown to exist between the time and temperature used to cook meat and the types of mutagens produced during the process. Agents that are mutagenic to humans may be present in food as natural components, as additives or contaminants, or as a result of processing or cooking. In 1983, scientists will investigate the nature of the principal mutagens more closely, assess their risk to humans, and consider possible strategies to prevent their formation or to control the risk of consuming foods contaminated by them. Efforts will also concentrate on the early detection of genetic damage by environmental chemicals.

Heart Disease

Public awareness of heart disease risk factors has caused changes in lifestyle that are thought to have contributed to a decreasing incidence of heart disease. For example, smoking has decreased in all segments of the population except young women; dietary changes that could be expected to decrease blood cholesterol have taken place in the Nation as a whole (and, indeed, average blood cholesterol has decreased nationally); and exercise has become more popular. Clearly, health consciousness is now very important in the American lifestyle.

While great progress has been made in disease prevention efforts, advances in the treatment of cardiovascular diseases also have been reported. For example, treatment of heart attack patients with the drug propranolol can save thousands of lives each year. A trial by the National Heart, Lung, and Blood Institute demonstrated a 26 percent drop in the death rate for heart attack survivors treated daily with propranolol—a beta-blocker that prevents some nerve impulses from stimulating the heart, arteries, and lungs and makes the heart more efficient. (The study was halted prematurely because the benefits of the drug were considered unequivocal.) At the same time, considerable promise is attached to another family of drugs, the so-called calcium channel blockers. These agents work essentially by causing relaxation in muscular walls of the arteries and appear to have great potential in the treatment of angina and high blood pressure.

Another important achievement is the development of the balloon angioplasty technique as a substitute for coronary bypass surgery in a limited number of cases of coronary artery obstruction. With this technique, such obstruction can sometimes be corrected by means of an inflatable balloon threaded into the artery via a catheter. Other recent accomplishments in cardiovascular research include development of synthetic blood substitutes ("perfluorochemicals") and rapid and dramatic advances in techniques of noninvasive diagnosis.

Infectious Diseases

Infectious diseases remain one of the major health problems of this country and a leading cause of absenteeism from work and school. In recent years, the introduction of successful vaccines for meningitis, pneumonia, rabies, measles, and rubella has encouraged scientists to accelerate efforts to develop other vaccines. Indeed, the emergence of recombinant DNA and hybridoma technologies—coupled with an increased understanding of the immune system—provides new opportunities in this direction, as illustrated by the recent breakthrough on a vaccine for hepatitis B.

With the aid of the new techniques, scientists at the National Institute of Allergy and Infectious Diseases are now working on a "second generation" hepatitis B vaccine. They have recently synthesized it, bypassing the need for huge quantities of infected blood, the source of the current vaccine. The new methods open the possibility of producing pure synthetic vaccines for many other diseases, including sexually transmitted diseases, influenza, respiratory diseases of children, and pseudomonas infections in patients with cystic fibrosis.

The Aging Process

The changing age distribution of the American population has drawn attention to the need for research to enhance the quality of life for older people and to contain the costs of health care and dependency. A significant segment of the over-65 age group is now burdened by age-associated disease and by the lack of recognition that some of these disabilities are preventable and, indeed, reversible.

One of the worst fears of growing old is the loss of memory and awareness. Total intellectual impairment, however, is not an inevitable consequence of growing old. Recent observations from numerous independent studies have shown that dementias—abnormal declines in memory and cognitive ability—may result from an acceleration or exaggeration of the normal aging process.

The National Institute on Aging, the National Institute of Neurological and Communicative Disorders and Stroke, and the National Institute of Mental Health support or conduct research on this important health problem. For the immediate future, scientists are expected to concentrate their attention on the neurobiology of the normal aging nervous system—the blood-brain barrier, cerebral metabolism and blood flow, factors regulating cell death, and the neuroendocrinology of aging. In particular, they will explore the many promising leads to prevent or treat dementias through use of antiviral agents, enzyme replacement or enhancement, adjustments in dietary patterns, intellectual stimulation (exercise for the brain), and other measures.

Misdiagnosis of depression as dementia is also a major public health issue. Because depression is readily and effectively treated, research is under way to develop the optimal differential diagnostic workup for patients with Alzheimer's Disease to promote proper treatment and prevent inappropriate clinical disposition.

Meanwhile, research is illuminating other aspects of aging. For example, elderly people are often malnourished, and malnutrition is the source of many of their health problems. Other research indicates that the heart of an older person pumps about as well as that of a young adult and that any problems related to the older heart's ability to move blood must be considered the effect of disease—such as coronary artery disease—not aging. Twenty-five years ago, it was widely believed that aging and disease were one and the same. As more is learned about the mechanisms—not just the manifestations—of aging, these views are being revised.

Other Health Problems and Opportunities

Research in the health sciences proceeded along a broad front in 1982, responding both to new challenges and to continuing health problems.

Mental Health Research

Within the past several years, there has been an explosion of advances in the neurosciences, including such developments as brain imaging techniques and the identification and localization of naturally occurring substances in the brain that underlie cellular communication. These are making possible a fundamentally new understanding of brain function at the neuronal level, which has profound implications for the treatment of mental and emotional disorders.

Brain imaging techniques, such as positron emission transaxial tomography (PETT), are the outgrowth of a method formulated by scientists at the National Institute of Mental Health (NIMH) in the late 1970s for quantifying and charting local metabolic processes in the conscious brain. In 1982, NIMH investigators conducted scans of normal volunteers and clinical subjects suffering from such illnesses as schizophrenia and depression. Through this experimental work, clinical researchers found they were able to differentiate normal and aberrant neuronal functions and, thus, pinpoint brain loci that appear to be implicated in disease processes.

Last year, NIMH scientists reported studies in which a second imaging technique—autoradiography—is used to map opiate receptor sites in the brain and central nervous system. Whereas PETT scanning provides a global picture of energy expenditure in the brain, the receptor mapping research provides much greater detail on location and type of neural activity. The combined power of the research approaches portends an era of "rational pharmacotherapy" in psychiatry, in which psychoactive medications will be designed purposefully to act on specific brain sites with minimal side effects.

Acquired Immunodeficiency Syndrome

In 1982, considerable public attention was drawn to the mysterious immune system disease "acquired immunodeficiency syndrome." On the average, four to five new cases are reported daily, and the death toll was more than 300 at the end of 1982. Survivors diagnosed as having the disorder continue to be susceptible to many fatal infections and Kaposi's sarcoma (a skin cancer)—that invade after the initial disease destroys the body's immune system. The syndrome, which was initially detected among homosexual males, is now apparently increasing in incidence. The epidemic is so unusual that it has no known parallel in history, and no other disease has been recorded in which immune system failure was spread from person to person. Available evidence suggests that the cause may be a virus transmitted through the blood or other bodily fluids.

National Institute of Mental Health

A dark-field photograph shows opiate receptors in a rat brain.

Multiple Sclerosis

The past year has brought significant accomplishments in the fight against multiple sclerosis (MS), the progressively disabling disease of the central nervous system that primarily affects young adults. MS is characterized by loss of myelin, the substance that surrounds many fibers of the nervous system. In 1982, scientists from the National Institute of Neurological and Communicative Disorders and Stroke identified what appears to be the earliest detectable biochemical change in MS thus far—a reduction in myelin-associated glycoprotein when MS attacks the body. Although effective treatment regimens are not yet available, scientists are studying potentially useful therapies, including immunosuppressive agents (cyclophosphamide and agathroprine) that reduce the frequency of acute attacks or modify the course of chronic progressive MS.

Space and Nuclear Medicine

On the fourth flight of the Space Shuttle Columbia, the United States took its first step toward using a low-gravity environment to improve the separation of biological materials and to achieve the production of new pharmaceuticals for the treatment of human disease. Samples used for these tests consisted of concentrations of albumen mixtures (which are difficult to separate on earth) and concentrations of cell culture media containing products of potential commercial interest.

In 1982, scientists using the JANUS nuclear reactor (the only biological research facility in the United States producing neutron exposures without the usual contaminating gamma rays) demonstrated at the Argonne National Laboratory that repeated small doses of neutron radiation are more carcinogenic than an equivalent total dose received in a short period of time. Such experiments are helping to improve estimates of risk to workers at nuclear facilities, as are studies of occupational exposure conducted by the Nuclear Regulatory Commission.

Biomedical Information Transfer

There is evidence that the conventional methods of information storage and transfer in biomedicine are reaching the limits of their usefulness and that a major step in the method of transferring human knowledge is needed. Instead of a list of journal articles, physicians and scientists need efficient access to dependable facts about a particular disease, biochemical process, drug, or procedure relevant to the problem confronted. The critical developments needed to provide such access will have to come from research on the structure of knowledge and the dynamics of perception, thought, and memory.

The National Institutes of Health has supported the development of a number of medical computer systems that mimic decisionmaking processes of experts. One of these systems, CADUCEUS, located at the University of Pittsburgh, is considered so "sophisticated" that it could be a board-certified internist if it were a human. Systems like CADUCEUS would be used in hospitals and laboratories as a consultant to medical personnel considering a combination of symptoms to make a diagnosis. This expert consultant would possess decades of medical experience, an infallible memory for past cases, and an encyclopedic knowledge of symptoms and diseases. While some physicians remain cautious about such applications of computers, others are predicting that consultation by diagnostic computers will soon be widespread.

International Biomedicine

The Fogarty International Center (FIC) is the focal point for the conduct and coordination of international activities in the health sciences; in 1982, at the request of the World Health Organization (WHO), it was designated a WHO Collaborating Center for Research and Training in Biomedicine. The Agency for International Development (AID) also supports health-related activities in the developing countries.

In 1982, the United States participated in a variety of internationally focused activities:

(1) The Pan American Conference on Health Research Policies was held in Caracas, Venezuela, in April 1982 to encourage the formulation of a health research policy by Ministers of Health in Latin America and the Caribbean as an integral part of the national health plan of each country.

(2) With support from AID, the National Institute of Allergy and Infectious Diseases is coordinating a research project with Israeli and Egyptian scientists on arthropod-borne diseases. Egyptian and Israeli scientists are now cooperating directly on health-related projects relating to three insect-borne diseases: malaria, Rift Valley fever, and leishmaniasis.

(3) in March 1982, FIC sponsored an International Symposium on Measles Immunization. An International Symposium on the Control of Poliomyelitis has been scheduled for March 1983.

(4) The Alcohol, Drug Abuse, and Mental Health Administration, in collaboration with WHO, convened the Conference on Classification and Diagnosis of Mental Disorders and Alcohol- and Drug-Related Problems

in April 1982, culminating a 2-year international effort to improve existing methods of classifying these disorders. More than 50 nations, including Eastern European and Third World countries, participated in the project.

(5) Under the terms of the Cooperative Health Agreement between the United States and the People's Republic of China, an NIMH scientist assisted in establishing a research facility in Peking dedicated to studies of schizophrenia, a major public health problem in both countries. Two visiting Chinese scientists collaborated in studies on schizophrenia and psychotropic drug metabolism.

The United States has also supported international health activities in tropical medicine through the Special Program for Research and Training in Tropical Diseases, sponsored by WHO, the United Nations Development Program, and the World Bank. There have been a number of promising leads for the control of several diseases:

- *Malaria*—Two new drugs, meyloquine and artesemin, have been developed and tested for use against chloroquine-resistant strains of malaria.
- *Schistosomiasis*—New drugs have been tested for four types of human schistosomiasis in different ecological settings, and Centers for Disease Control (CDC) authorities have reported a dramatic reduction of infection rates with the drug praziquantel.
- *Trypanosomiasis*—A simple diagnostic test for African sleeping sickness that gives immediate results in the field has been developed.
- *Leprosy*—A recently developed vaccine is now being tested in man.

The Reagan Administration's energy policy seeks to facilitate the economically efficient development of the Nation's resources. It is part of an overall economic policy that calls for less Government spending, less regulation, and greater reliance on market forces.

Federal R&D should provide industry with the scientific and technical knowledge base to enable the development of new technologies to exploit available resources. Future energy reliance on our domestic resources of coal and uranium also requires continuing efforts to understand environmental and public health impacts of associated technologies.

During the past year, there were many accomplishments in Government-financed energy-related research. The following are considered most noteworthy:

- Experiments have shown that the current in pulsed tokamaks could, alternatively, be driven by induction and microwaves, or could be sustained by a steady-state application of microwaves, eliminating the negative effects of pulsed operation and making the tokamak more attractive as a fusion reactor;
- Hydrotreating of coal has been shown to produce dramatic reduction in the bioactivity of the full boiling range of coal liquids, mitigating the effects of those chemicals in the coal conversion process that are not only carcinogenic, but also accelerate (promote) the development of cancer;
- Cracking of iron-nickel-chromium alloys (such as those used in steam generator heat-exchanger tubing in nuclear reactors) due to sulfur in aqueous solutions has been shown to be inhibited by boron ions, leading to the control of cracking by regulation of the thiosulfate/borate ion ratio in the cooling water; and
- A three-order-of-magnitude improvement in the precision of measuring sulfur isotope ratios in the air was achieved, critical to establishing a reliable measurement to identify sources of acid rain.

The following pages highlight the trends and accomplishments of Federal energy research and development programs to support the Administration's energy policy. They are divided into three sections: fundamental energy research, providing for long-term energy needs, and protecting the public and the environment.

Fundamental Energy Research

Long-term fundamental research in traditional scientific disciplines—principally materials science, chemistry, and physics—provides the foundation for solving many energy problems.

Materials Science

The limitations in development of many energy technologies result from materials problems, so that Government research has focused on providing greater understanding of materials properties and behavior. Among the recent results, a new phase of matter in the erbium rhodium boron compound, $ErRh_4B_4$, was first observed directly in the temperature range where ferromagnetism, linearly polarized oscillatory magnetism, and superconductivity coexist. Prior theories had indicated that this coexistence was impossible. The discovery, therefore, has generated considerable theoretical and experimental interest in the nature of transitions from superconductivity to magnetism and the conditions for possible coexistence of those two properties.

It was also found that cracking of iron-nickel-chromium alloys due to sulfur in aqueous solutions is inhibited by boron ions. Inconel 600, a nickel-base alloy, is the principal commercial alloy used in steam generator heat-exchanger tubing in nuclear reactors. Intergranular stress corrosion cracking of the tubing can be inhibited by regulating the concentration of thiosulfate to borate ions. Reactor engineers can control this ratio by adding other salts to the cooling water.

Chemistry

Researchers recently achieved a three-order-of-magnitude improvement in the precision of measuring the sulfur isotope ratio (S_{32}/S_{34}) in air. This was accomplished using negative ion mass spectrometry rather than the current practice based on positive ion mass spectrometry. The latter is of limited value because of the cumbersome equipment involved and the excessively long measurement times required. The greatly improved precision in determining sulfur isotope ratios is critical to establishing a reliable measurement tool for identifying the sources contributing to acid rain.

Another significant scientific result was the discovery of large cluster ions, a new kind of chemical species. These ions are weakly bound assemblies of thousands of molecules with a positive or negative electrical charge. They are stable as long as they are isolated from other molecules; but, if introduced into gases in which they can undergo collisions, the cluster ions will either self-destruct or grow into much larger stable solids or liquids. Recently, a very low temperature ion source was constructed to generate cluster ions containing thousands of hydrogen molecules with a single positive charge. These positively charged cluster ions can be accelerated in properly designed linear accelerators, leading to the creation of microplasmas at very high temperatures. Such microplasmas may be relevant to the development of inertial fusion, offering an intermediate approach between heavy ion fusion and impact fusion.

Most chemical processes require large quantities of fluid-handling equipment. Fluid properties, essential to proper process design, have traditionally been derived from empirical data and are often used far beyond the range for which the data pertain. The National Bureau of Standards has developed a computer model that makes possible a more refined determination of important fluid properties for a large number of chemicals of major interest to the processing industry.

Physics

The fundamental constituents of matter and energy, the forces between them, and the physical laws governing their interactions form the basis for all the physical sciences. Deeper understanding correspondingly contributes, sometimes in spectacular ways, to solution of many energy problems as well as to all of the scientific disciplines.

Of the four forces of nature, the strong nuclear interaction force has been the most difficult to systematize into a credible theory. This has been due to a diversity of physical phenomena for which the strong force is responsible (fission, fusion, new kinds of matter, etc.) and the large energies associated with the strong interaction. The emergence of a theory of strong interactions, known as quantum chromodynamics, has had a number of major successes this past year. For example, a new technique has been developed to calculate actual particle masses. This, together with the development of algebraic computing codes, makes it possible to apply the theory quantitatively to complex strong interaction phenomena.

Several major experimental efforts are under way to determine whether the proton, the nucleus of hydrogen, which makes up

Lawrence Berkeley Laboratory

The head-on collision of an argon nucleus with a lead nucleus.

about 90 percent of all matter in the universe, is stable. Recent progress in high-energy theory toward an eventual unified description of the fundamental forces of nature has led to the astounding prediction that the proton, the basic building block of ordinary matter, will be found to be an unstable particle with an exceedingly long lifetime. The predicted lifetime is so long that it is at the boundary of experimental limits for determination. An experiment in a gold mine has pushed the proton's lifetime upward to the 2 x 10^{30} year range. Two new large detectors have been assembled this past year in a salt mine and a silver mine. Experiments with these detectors will allow observation of proton decay events in the lifetime range of up to a factor of 100 times the present limit, or about 10^{32} years.

The most important initiative in high-energy physics is the Stanford Linear Accelerator Center's Linear Collider project, a facility to accelerate and direct beams of electrons and positrons against each other. The new technology promises to accelerate the electrons and positrons to much higher energies than is, at present, technically and economically feasible. If the potential of the system is realized, the total energy available in the colliding electron-positron system could be increased by a factor of about three above that now available and would thus open an important new energy region for fundamental particle research.

At Fermilab, new superconducting accelerator magnets form a sector of the 1,000-magnet ring called the Energy Saver Project, which, in 1983, will be the first operating superconducting accelerator for high-energy physics research. A series of these magnets was repeatedly cycled on and off under simulated operating conditions without a single magnet failure. The project will provide a higher energy proton beam at substantially lower power costs. It is also the basis of further upgrades that will give the United States a leadership role in proton accelerator facilities in the mid-1980s.

Advanced Energy Projects

The feasibility of several scientific concepts having potential energy applications was explored.

One recent accomplishment has been the development of a liquid membrane for enriching the oxygen content in air. Oxygen is preferentially transported across the membrane by a chemical agent that plays a role analogous to that of hemoglobin in blood. Oxygen enrichment is several times more efficient with the liquid membrane than with solid membranes; and oxygen-enriched air, important for efficient combustion and crucial for high-BTU coal gasification, can now be produced with great savings in energy and cost.

Another major research result was the development of a new class of electronic materials formed as quasi-one-dimensional organic polymers, which have the properties of semiconductors or metals when suitably doped with donor or acceptor species. The prototype of these conducting polymers is polyacetylene (CH_x), which can be prepared as a silvery, flexible film, either free standing or on a variety of substances such as glass or metal, with thicknesses varying from 10^{-5} to 0.5 centimeters.

Providing for Long-Term Energy Needs

In selected areas where industry is not investing sufficiently because of the too distant return, Government R&D has gone beyond fundamental research to focus on advanced technologies with high potential for meeting long-term needs.

Nuclear Power

The Fast Flux Test Facility (FFTF), located at the Hanford Engineering Development Laboratory near Richland, Washington, is the prime R&D tool supporting breeder reactor research. The FFTF successfully accomplished full-power test operation and was dedicated in February 1982. The facility is now providing scientists and engineers with data on advanced breeder fuels and materials to build safe, reliable, and economic breeder reactors.

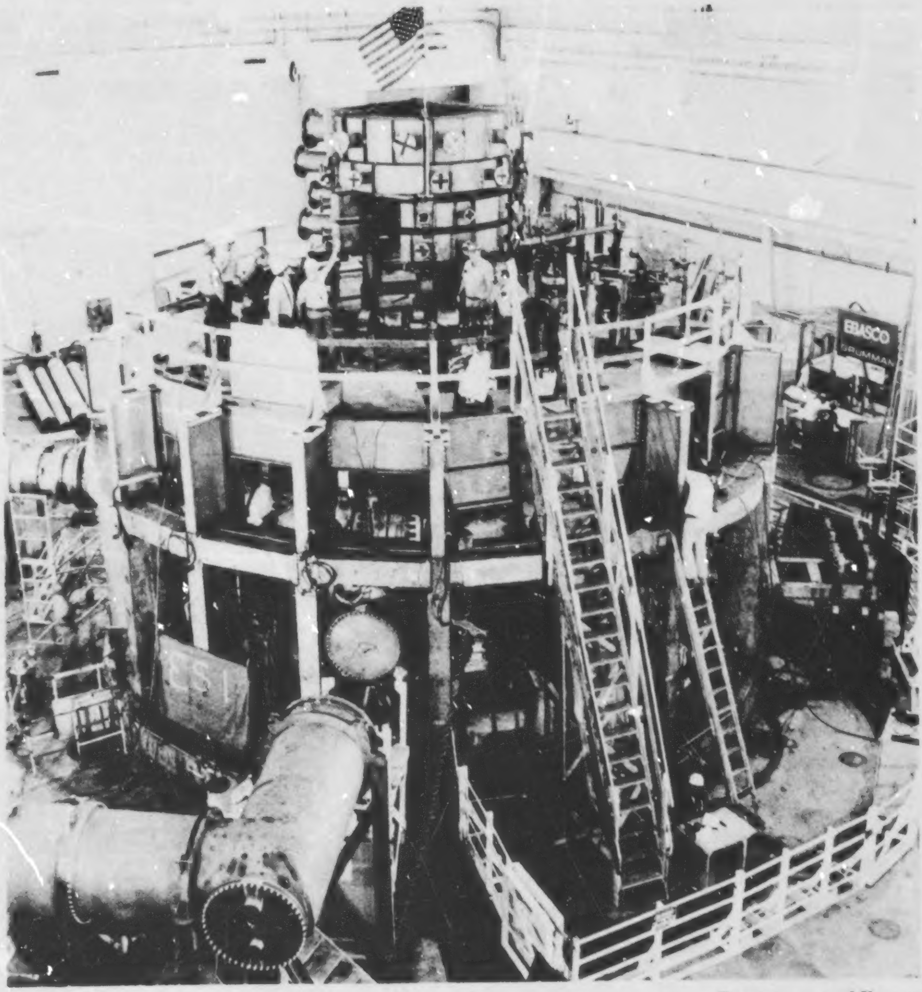
More efficient enrichment techniques can extend the uranium resource base. During 1982, the Atomic Vapor Laser Isotope

Separation process, an advanced technique for enriching uranium, was selected for large-scale engineering development and demonstration. It is based on the concept that different uranium isotopes selectively absorb radiation in different regions of the energy spectrum. This selective absorption can then be used to separate the desired uranium isotope.

Nuclear Fusion

Magnetic fusion is a long-term energy option that could become a principal energy source in the next century. It has an inexpensive, vast, and secure fuel reserve, as well as environmental and safety aspects that appear to be desirable. While electricity is an obvious end use for fusion, other possible uses include breeding fissile material for fission plants, generating high-grade heat for industrial applications, and the direct production of synthetic fuels.

During the last three decades, the Government's magnetic fusion development program has been successfully resolving the basic scientific and technological issues associated with the production, heating, and confinement of high-temperature plasmas in magnetic fields. This phase of the pro-



Department of Energy

The Tokamak Fusion Test Reactor machine assembly at Princeton University immediately prior to initiation of test operations.

gram is entering its final period with the completion of the Princeton University Tokamak Fusion Test Reactor (TFTR) facility, designed to demonstrate the scientific feasibility of magnetic fusion energy generation. The TFTR facility achieved its first plasma for system-testing on December 24, 1982, and is currently undergoing its initial shakedown testing. The achievement of energy breakeven, i.e., the generation of as much fusion energy as it requires to heat the fusion plasma, is expected to be reached in 1986.

Progress in tokamak confinement physics in existing facilities has also been encouraging. Radio frequency plasma heating has been demonstrated to be comparable in efficiency to neutral beam heating. Techniques for driving the plasma current with radio frequency waves have been demonstrated in two test devices, the Large Torus at Princeton and Alcator C at the Massachusetts Institute of Technology, giving promise of the development of true steady-state tokamak operation. A plasma confinement efficiency (beta) of 4.6 percent has been achieved at G.A. Technologies Doublet III facility in San Diego. A beta of 5 percent is estimated as adequate for a tokamak power reactor. With the installation of additional plasma heating, it is expected that the beta value will be increased above 5 percent in fiscal year 1983.

The Tritium Systems Test Assembly (TSTA) at Los Alamos National Laboratory was completed in fiscal year 1982, providing a facility to demonstrate the technology for safe processing and handling of deuterium-tritium fuel for fusion reactors. TSTA is the program's first reactor-scale nuclear engineering facility.

Upgrading of the Tandem Mirror Experiment (TMX-U) at Lawrence Livermore Laboratory was completed in fiscal year 1982, and the experiment was put into operation. This device provides a means of examining the potential of the leading alternate to the tokamak as a fusion reactor confinement concept. Results obtained so far confirm expectations based on theoretical predictions.

The Mirror Fusion Test Facility (MFTF-B) construction project, also at Lawrence Livermore Laboratory, has completed its first phase, including demonstration of the technology for the project. This includes successful testing of the first superconducting Yin-Yang magnets, the vacuum vessel, and the vacuum, control, and cryogenic systems. Completion of this device in fiscal year 1987 will provide the program with a tandem mirror plasma confinement test facility roughly as advanced as TFTR.

International cooperation to supplement and complement the U.S. fusion development program has increased significantly. The major foreign partners are the European community and Japan. Selected scientific exchanges are conducted with the Soviet Union as well. The cooperative activities include sharing of research data, joint funding of multimillion dollar projects in the United States, and consideration of future joint funding and operation of major projects with other Western countries.

Protecting the Public and the Environment

The Government's role with respect to the health and environmental aspects of energy sources is twofold. Agencies such as the Department of Energy perform basic and applied research to understand the fundamental health and environmental impacts of energy technologies and the feasibility of controlling them. Regulatory agencies such as the Environmental Protection Agency and the Nuclear Regulatory Commission perform R&D to develop the understanding necessary to formulate environmental, health, and safety regulations.

Health Research

Energy-related research in biophysics, genetics, and cell biology aims to understand the structure, function, and interrelationships of the fundamental components of living organisms. With this knowledge, scientists can elucidate the basis for susceptibility of critical life processes to energy-related agents, identify early indicators of biological responses, and improve the basis for understanding and estimating risks to human health under various conditions.

Chemical mixtures in coal conversion process streams are known to produce delayed health effects, and a battery of reliable short-term bioassays to identify those chemicals that produce genetic damage or damage to somatic cells has been developed. The short-term screening has reduced the number of chemicals that require further evaluation via more conventional long-term animal assays.

Specifically, tests have found that the larger ring polycyclic hydrocarbons or similar compounds in coal liquefaction process streams appear to be responsible for coal liquid carcinogenicity. Of these, the polyaromatic amines have been found to be the most active mutagens. Identification of these substances in the high boiling end of the product slate has been important in suggesting future methods for dealing with these chemicals.

Nuclear Waste Management

During 1982, the Reagan Administration gave priority to addressing the resolution of the nuclear waste problem. It strongly supported the Nuclear Waste bill, which was approved by Congress in December 1982 and signed into law in January 1983. Potential sites for a Federal repository have been identified.

Current research aims to predict the performance of engineered barriers for containing wastes and controlling the release of radionuclides. During 1982, research was conducted on a neutron activation instrument, originally developed by the National Aeronautics and Space Administration to detect various elements in place during a lunar experiment. The instrument employs a pulsed-neutron generator and several gamma ray detectors and will be tested in tuff rocks from a waste repository test site. Research on this instrument could lead to the development of a device to detect the seepage of nuclear wastes into the surrounding rock.

Nuclear Reactor Safety

Following the number of technical reviews after the Three Mile Island (TMI) accident, the Nation's nuclear safety program was given increased overall priority and a number of new areas were identified for increased research emphasis.

The Nuclear Regulatory Commission has instituted a program in human engineering to study such areas as advanced control room concepts, human factors standards development, and operator licensing effectiveness. Research is under way to improve understanding of the man-machine interface during the spectrum of accident sequences, with the goal of preventing and mitigating severe accidents.

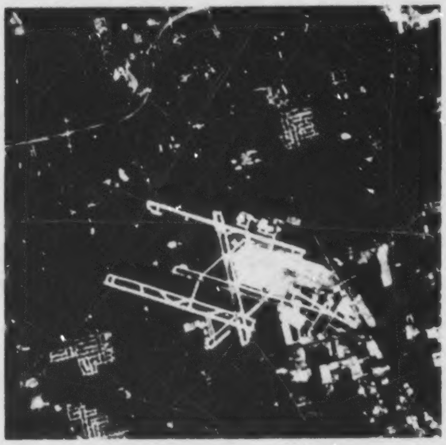
Several major experimental programs are under way to test safety features under reactor accident conditions. The tests are of two types, those measuring the performance of the integral reactor system and those testing separate subsystems. Integral tests take place in three facilities. The Loss-Of-Fluid Test (LOFT) facility was designed to evaluate the safety of commercial reactors. In the last few years, it was expanded to include the study of ways to control an unplanned transient in power production and to test the extent to which instrumentation and diagnostic systems are effective aids to reactor operators. An international consortium to operate LOFT in future years is being established under the aegis of the Nuclear Energy Agency. Two other facilities, Semiscale and FIST, simulate the pressurized and boiling water cores. Test plans for all three facilities have been modified to include loss-of-coolant accidents resulting from breaks of small pipes (as during the TMI accident) as well as those of large pipes. At other facilities and in Canada, fuel-behavior research emphasizes accidents involving severe core damage, such as the event at TMI-2.

The primary system in a nuclear reactor, comprising the pressure vessel, primary piping, and steam generator, is the major defense against radioactivity release during severe accidents. These components are particularly vulnerable because they must operate in a hostile environment. The aging process is accelerated by irradiation. Current research activities are directed toward predicting stress levels and flaw sizes of cracks in pressure vessels and primary piping and determining changes in fracture toughness resulting from radiation, thermal aging, and corrosion. In fiscal year 1982, a facility to analyze vessel fracture under pressurized thermal shock conditions was constructed. A program on pipe failures was completed, and a study on the capacity of cracked pipes to withstand postulated accident and transient loading was begun. Emphasis will be placed on the effects of stress and corrosion in steam generators and piping and on developing criteria for acceptable welding.

The Reagan Administration believes that management of the Nation's natural resources is an important Federal Government responsibility. A proper balance that will allow economic progress, a minimally disturbed environment, and materials security for the United States must be achieved. Scientific research to support this mission is divided among a variety of Federal agencies including the Departments of Agriculture, Commerce, Energy, Defense, and Interior, the National Aeronautics and Space Administration, and the National Science Foundation.

Among the most promising natural resource developments in the past year, several may be highlighted as truly outstanding with long-term beneficial applications. These include:

- Investigations of new mineral-rich polymetallic sulphide crusts being formed along Oregon's Gorda oceanic spreading-center ridge, which may provide an important source of critical minerals in the future;
- Launch on Landsat-4 of the Thematic Mapper, which has the ability to acquire and process data of superior quality and holds promise for many new applications in civil remote sensing; and
- Development of a wood system for home building that uses less timber and which could lower housing construction costs by 10-30 percent.



National Oceanic and Atmospheric Administration

A high-quality image obtained from the Landsat 4 thematic mapper.

The following paragraphs describe some new developments and accomplishments in several natural resources areas: U.S. minerals policy, critical materials, ocean minerals, remote sensing, fisheries, and forest resources.

U.S. Minerals Policy

In April 1982, President Reagan submitted to Congress the Administration's first national minerals policy report as mandated by the National Materials and Mineral Policy, Research, and Development Act of 1980. This policy recognizes "the critical role of minerals to our economy, national defense, and standard of living" and stresses "America's need for measures to diminish minerals vulnerability by allowing private enterprise to preserve and expand our minerals and materials economy." The policy report focuses on land availability for exploration, materials research and development, minerals and materials data collection, and a strategic materials stockpile.

Currently the United States imports more than half of its total supplies of 20 strategic minerals. Concerned about our increasing reliance on foreign sources for critical materials, the Administration has undertaken the first stockpile purchase program in 20 years. In addition, the Administration will continue to encourage materials research and development in the private sector through such incentives as tax credits. Continued Federal efforts will be made to collect international minerals data and use it to monitor trends and events affecting supply and demand.

Critical Materials

Mineral resources, the basis of materials supply, are vital to defense and to a healthy economy. Substantive research efforts on materials and minerals are conducted by the Department of Defense (DOD), the Department of Commerce's National Bureau of Standards (NBS), the Department of the Interior's Geological Survey (USGS) and Bureau of Mines, the National Aeronautics and Space Administration (NASA), and the Department of Energy (DOE).

Cobalt, chromium, titanium, and tantalum are critical and strategic materials, susceptible to supply disruptions, shortages in processing capacity, and rapid price increases. In some cases there are no effective substitutes. Therefore, to protect against supply disruptions that may endanger the national security, it is the Administration's policy to rely primarily upon our National Defense Stockpile. In addition, to reduce the risks inherent in wartime supply disruptions, a combination of efforts is under way. These include basic, long-term research on understanding the roles of the alloying elements cobalt, tantalum, and columbium in critical gas-turbine engine alloys; search for improved substitution materials for alloys having a high content of strategic elements; conservation and reduction of scrap generated during fabrication of components; and recycling of scrap.

Advanced materials technology research is directed toward more efficient use of these critical minerals. First, basic research to develop composites that use organic and metallic reinforcements to increase strength and stiffness is under way. Polymers, ceramics, and metal composites are being investigated; carbon filament composites with epoxy matrices are receiving wide use. A second important research area is rapid solidification technology, which consists of cooling liquid metals extremely rapidly to produce materials with improved strength and corrosion and fracture resistance properties. New alloys with these characteristics are being developed, for example, for aircraft engines, which must operate at elevated temperatures.

Investigations of such advanced techniques as fusion welding, solid-state bonds, brazes, and adhesives for joining diverse materials are also under way. Vapor deposition, ion implantation, beam blending, and laser annealing techniques are being used to improve specific surface properties such as corrosion and wear resistance. Diagnostic techniques involving laser and particle beams are finding rapidly expanding applications.

An important materials research program conducted by the National Bureau of Standards in cooperation with the American Society for Metals and the American Ceramic Society is a worldwide effort to gather, evaluate, computerize, and disseminate alloy and ceramic phase diagrams. These diagrams have been described as "road maps" for the design and processing of materials. They are the graphic representations of crystallographic phases at different compositions and temperatures. Phase diagrams serve a variety of useful scientific and technical purposes, including design of new alloys and ceramics for substitution of scarce materials, efficient use of ores, and development of suitable processes for materials fabrication to minimize waste.

The research efforts of the Department of the Interior's Bureau of Mines and Geological Survey are wide ranging and concentrate on long-term, high-potential areas of science and technology. Four new Minerals Research Centers were established at universities this past year to conduct generic research in cooperation with industry in comminution, pyrometallurgy, underground mining, and mineral waste. Also, efforts are being made to develop economic methods to recover nickel, cobalt, and chromium from low-grade laterite deposits in Oregon and California. In metallurgy, researchers are seeking substitutes for chrome in alloy steel, with possible reductions of more than a half in the amount of chrome required in some alloys. Work is also under way on developing rapid scrap identification and separation methods for nickel-base alloys and stainless steel using thermoelectric response and optical emission spectroscopy. Rare-earth/cobalt magnets currently being developed are comparable in performance to existing samarium/cobalt magnet alloys used in space vehicles and other applications. The new magnet alloy uses no samarium, supplies of which are limited, and less cobalt. Research on improved magnesia refractories used for metallurgical furnaces could eliminate the need for imported chromite.

Basic research in the Bureau of Mines on the use of sulfur as a construction material resulted in new technology to control deleterious crystallographic transformations and spawned a new sulfur concrete highly resistant to acid and salt corrosion. Other research in fine particle ceramic technology may lead to significant advances in structural materials, particularly important in high-temperature applications.

One of the DOE laboratories is developing a powder metallurgy process to replace metal casting in the fabrication of reactor fuel and target assemblies. Research objectives include improved quality, less waste, lower operating costs, and more efficient fuel use. A mockup of the process has been installed and tested successfully.

As part of its expanded effort to locate additional domestic supplies of minerals, the U.S. Geological Survey revitalized research on the geology of mineral deposits. Modern understandings about plate tectonics and mineral deposits enable USGS geologists to identify crustal fragments and terranes that are most promising for the discovery of new economic mineral deposits. New mineral deposit models are being developed, including ones for manganese, nickel, and platinum. The USGS is also developing new geochemical and geophysical techniques for exploration of deep mineral deposits in the midcontinental United States.

Ocean Minerals

Ocean-floor sulfide ore deposits could be of vital importance to the United States. Some estimates suggest that as many as 20 of the 30 strategically short minerals used by this country may be available in sulfide deposits within the 200-mile Exclusive Economic Zone of the U.S. West Coast. These new sources may make it possible for the United States to lessen its reliance on foreign sources of critical and strategic minerals.

Cooperative programs between privately sponsored and Federal marine geology researchers have disclosed mineral-rich hot springs along oceanic spreading-center ridges, where the tectonic plate separating rate is 2 inches or more per year. New polymetallic sulfide crusts are being formed along significant portions of the 45,000 miles of these ridges by the upwelling of molten rock from the underlying mantle. In 1982, researchers investigated large areas of the seafloor ridges off the coasts of California, Oregon, and Washington as well as the Blake Plateau off the East Coast.

In addition to resources at spreading centers, a significant new potential source of cobalt has been recently identified in cobalt-rich ferromanganese crusts of the mid-Pacific Seamount and Line Islands area of the central Pacific Ocean. Each of the many seamounts in the area is indicated to contain several millions of tons of ferromanganese crust having significant amounts of cobalt, manganese, nickel, and other minor valuable metals such as molybdenum, vanadium, copper, and platinum.

New sonar bathymetric surveying methods make it possible to map 100 percent of a given region in a minimum of ship time and to acquire great detail of the ocean-floor topography. These fine-scale measurements provide vital information about the geological processes occurring at the sea-floor ridges.

Knowledge of geologic systems gained by current marine research may also be directly transferable to investigations for new on-shore mineral occurrences. For example, some of the on-shore volcanic rocks (known as ophiolite sequences) were once underwater and have characteristics similar to present-day ocean formations. Federal agencies conducting or supporting this type of research are the National Oceanic and Atmospheric Administration (NOAA), the National Science Foundation and the USGS, with associated programs by the Office of Naval Research.

Remote Sensing

On July 16, 1982, the fourth Landsat satellite was successfully launched, just 10 years after the first Landsat satellite (ERTS-1) began providing a continuous flow of remotely sensed natural resource data. Such data have provided researchers with the ability to study large areas at one glance, since each Landsat scene covers 13,000 square miles (roughly the size of the combined areas of Connecticut and Massachusetts). Landsat 4 covers the earth every 16 days. It is carrying and testing the Thematic Mapper, a new, state-of-the-art sensor that provides new and narrower spectral bands and that produces images with better spectral and spatial resolution and which are more accurately correlated with actual ground location than previous sensors. The Thematic Mapper is being operated initially by NASA as an experimental sensor, but it will be taken over by NOAA when it has reached operational status and is producing 50 scenes per day.

Landsat 4 is also carrying a new communications and data-handling module that will tie in with the NASA Tracking and Data Relay Satellite System scheduled to become operational in 1984. This system will relay Landsat data to earth almost instantaneously. Such increased speeds in delivery of data will be invaluable in monitoring flooded areas, forest fires, iceberg flow, and other situations where receiving the data immediately is critical.

Fisheries

An important research breakthrough in 1982 was the chemical isolation of ciguatoxin, a compound that accumulates in some Caribbean and Pacific seafoods and causes serious human illness and, occasionally, death. The isolation of this chemical may lead to a rapid test for its presence in coral reef fish, for example, red snapper and grouper. A reliable test would allow contaminated fish to be removed prior to sale, and, eventually, marine areas that yield toxic catches could be identified to fishermen.

Marine fishery resources contribute nearly $4 billion annually to the U.S. economy. Scientists are now starting to apply satellite-derived oceanographic data successfully to fish stock assessment. For example, data have assisted in providing synoptic coverage of environmental processes affecting the distribution, migration, and spawning of the northern anchovy. Satellite imagery is being used to assist West Coast tuna fishermen in locating the best fishing areas. An ocean-color sensor on NASA's Nimbus-7 satellite is transmitting data on water clarity, which NOAA then processes and provides daily to fishing vessels.

Forest Resources

The Department of Agriculture's Forest Service develops scientific and technical knowledge for enhancing the economic and environmental value of America's 1.6 billion acres of forest and associated rangelands. Forest Service scientists work closely with researchers from other public agencies, forest industries, forestry schools, and agricultural experiment stations. Recent research advances are described in the following paragraphs.

To extend the Nation's timber supply, the Forest Service's Product Laboratory has invented and patented a Truss-Framed System (TFS) for building homes, which combines floors, walls, and roof into a unitized frame. TFS reduces the need for structural framing lumber and uses smaller size timber. Overall construction costs are lowered 10-30 percent by reduced material and labor costs. An additional benefit of TFS is its resistance to severe storms and earthquakes. The Forest Service is conducting a 3-year technology implementation plan.

Slash and loblolly pine trees have been developed that are resistant to a serious plant disease, fusiform rust, which presently causes losses estimated at over $100 million annually. Testing of the new genetically improved trees shows loblolly pine losses reduced by 40 percent and reductions of 50 percent for slash pine. By 1985, the annual output of seedlings for these genetically superior trees will reach 15-20 million. Use of this stock will result in significant savings for growers of southern pines, who produce almost half of the Nation's round wood supply.

An early warning system for detecting rising populations of the Douglas fir tussock moth, which destroyed about 800,000 acres of prime northwestern U.S. forest land from 1971-1974, is being tested and refined. After detection, the moths are treated with a virus that maintains or reduces the insects to manageable levels, with resultant overall savings through lower tree-treatment costs and higher forest yields.

Forest Service

A Douglas-fir tussock moth killed by application of a virus.

The Reagan Administration recognizes the Government's responsibility in safeguarding the environment and supports research to improve its regulatory function. In 1982, federally sponsored environmental research led to progress in many areas. Some significant accomplishments were:

- The precise ozone concentration that decreases human pulmonary function was defined;
- At the completion of a series of studies, the use of small portable monitors will provide for more accurate determinations of actual human exposures to carbon monoxide;
- A new screening test that greatly reduces the cost of testing chemicals for their proclivity to produce birth defects was developed; and
- A culture of microorganisms capable of "eating" and breaking down the toxic substance 2,4,5-T was laboratory tested.

The following sections highlight the trends and accomplishments of Federal environment research and development programs. They describe more sensitive and less expensive tests for pollutant toxicity; improved techniques for detecting, measuring, and controlling pollutants in water and air; more effective ways to deal with toxic substances and hazardous and radioactive wastes; and new ways to detect and predict the impacts of natural hazards.

Measurement and Monitoring

The detection, measurement, and monitoring of pollutants, necessary for setting and enforcing environmental standards, are sometimes extremely difficult. Improvements were made in 1982 in the measurement and monitoring capability for several major pollutants.

Asbestos

For several years, the Environmental Protection Agency (EPA) has been investigating Polarized Light Microscopy (PLM) and X-ray Defraction (XRD) techniques for measuring asbestos fibers released from ceiling and other bulk insulating materials. Researchers from EPA and the Department of the Interior's Bureau of Mines developed protocols that will allow these techniques to be used to detect dangerous asbestos conditions.

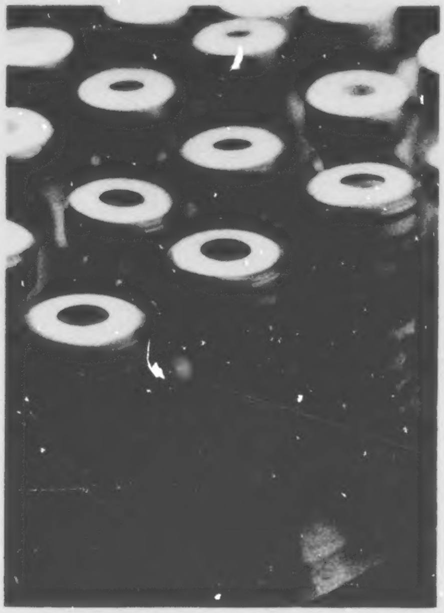
Polychlorinated Biphenyls

Polychlorinated biphenyls (PCBs) are highly toxic agents that were used widely as fire retardant coolant additives in electrical systems. Although their manufacture has been banned for most applications in the United States, PCBs are long lasting, difficult to detect, and have been mistakenly added to oil stocks and thus recycled. A hybrid analytical technique developed by scientists at the National Bureau of Standards (NBS) combines gas chromatography with high-performance liquid chromatography to achieve detection sensitivities of PCBs of less than one part per million. This new measurement technique should prove most useful to the electrical industry, the oil-recycling industry, and environmental monitoring officials.

Organic Compounds in Water

One of the more intractable problems in controlling toxic industrial effluents is measuring the concentrations of organic compounds in industrial wastewater. A standard method for detecting those compounds involves the use of gas chromatography/mass spectrometry systems. Such systems require the separation of the spectral signature of one organic compound from the signatures of as many as several hundred other organic compounds in the same sample. To do so manually was an exhausting, time-consuming, and inexact effort. Researchers at EPA have developed a computer support system that now can identify the spectral signatures of more than 1,500 different organic compounds. The system has been used to analyze approximately 4,000 industrial wastewater samples.

In addition, a master analytical scheme for the analysis of volatile organic compounds in water has been developed. The scheme



Environmental Protection Agency

Accurate testing of environmental contamination requires careful sample control.

provides guidelines to enable the measurement of a broad spectrum of organic compounds. In 1982, EPA used the technique to conduct a comprehensive analysis of organics in U.S. drinking water. The water supplies of seven U.S. cities were analyzed, and organic pollutants from them were tested for mutagenicity and carcinogenicity.

Water Pollution

To meet the requirements of the Clean Water Act, EPA establishes criteria for water quality necessary to support aquatic life. Last year, EPA researchers produced water quality criteria documents that will allow environmental decisionmakers to assess the potential risk of adverse effects on aquatic life from seven major pollutants (arsenic, cyanide, cadmium, chromium, copper, lead, and mercury). The criteria documents are exhaustive compilations and evaluations of currently available scientific information.

Large volumes of sewage sludge are produced by wastewater treatment processes. This sludge may be disposed of by burning. However, sludge contains a large proportion of water, and, in 1980 alone, the equivalent of 120,000,000 gallons of additional fuel oil was needed to incinerate it. Scientists at EPA have developed a technique that allows the precise control of burning conditions at the incinerator. The optimum combustion reduces fuel requirements while also reducing the need for expensive air pollution control equipment.

Approximately one-half of the U.S. population relies on groundwater for drinking. In recent years, the discovery of synthetic organic chemicals in the groundwater of many northeastern states disproved the traditional belief that groundwater is naturally protected from pollutants. Not enough is known about how pollutants behave below the surface of the ground. To examine such pollutant behavior, EPA scientists have designed and constructed several laboratory-scale physical models of the subsurface environment through which pollutants travel. These microcosms, along with mathematical models based on them, are now providing environmental officials with more information on the movement and changes of pollutants underground and on how to prevent contamination of groundwater.

Marine Environment

The Nation's Atlantic, Pacific, and Gulf Coasts serve as major sources for food, commerce, and recreation. In fact, nearly 100 million Americans live within 50 miles of one of these coastlines.

The oceans have been used as dumpsites for municipal wastes. To determine the ability of a particular ocean site to receive municipal waste without extensive environmental damage, EPA scientists have developed a set of marine quality criteria for evaluating ocean outfalls. These criteria may help coastal cities save millions of dollars in construction and operating costs by careful identification of individual treatment needs and by discharging their effluents at ocean outfalls. The National Oceanic and Atmospheric Administration (NOAA) is also examining how wastes dumped at sea (as opposed to disposal by outfall or pipeline) affect the marine environment and whether rapid disposal at deep sites is feasible.

Oil may be the most serious widespread pollutant in coastal waters. Detection of accidental or intentional oil spills in time for adequate enforcement and/or cleanup activities has been a continuing problem. In 1982, the U.S. Coast Guard completed development of the AIREYE aerial surveillance system for effective, economical oil pollution detection. In addition to the timely detection of oil spills, this system has potential application in search and rescue missions and the enforcement of applicable laws and treaties.

In 1982, major research projects added significantly to knowledge of marine water quality. The Northeast Monitoring Program, conducted by NOAA, provided data for determining marine pollution trends, areas of concern, and potential impacts on commercially harvested marine organisms. In another effort, EPA researchers completed an exhaustive study of three Gulf Coast estuaries. Results suggest that, although far from being pristine, the estuaries were not severely unhealthy environments. These studies will serve as baselines for other periodic determinations of the health of coastal ecosystems in relation to increasing population and industrial growth.

Air Pollution

The costs of controlling air pollution are readily available, yet it is far more difficult to determine the costs associated with damage caused by air pollution. Knowledge of these costs is necessary in evaluating the costs/benefits of environmental standards.

Several studies were conducted to determine the cost of agricultural crop losses due to air pollution. The National Crop Loss Assessment Network will soon have assessed crops accounting for three-fourths of the total U.S. agricultural production value. Preliminary results indicate that nationwide agricultural economic losses due to air pollution appear to be between 2 and 3 billion dollars per year.

To determine the effect of coal-fired power plants on natural grasslands (upon which the cattle industry depends), EPA conducted a major sulfur dioxide (SO_2) effects study in southeastern Montana. The study concluded that SO_2 from power plants operating in compliance with current standards is not likely to adversely affect the native grasslands or the cattle that graze upon them.

In an effort to provide data on acid rain, an acid deposition data bank was established in 1982. The relationship between emissions and acid deposition is determined by measuring sulfur isotope ratios. Negative ion mass spectrometry was used to improve the precision of measuring that ratio by more than 1,000 times over previous techniques.

Toxic Substances

There are approximately 60,000 synthetic chemicals in commerce today, and nearly 1,000 new chemicals are added each year. Testing chemicals for toxicity can be extremely expensive. However, the potential risks from some chemicals can be estimated from their structural similarity to chemicals of known toxicity. In 1982, EPA researchers developed a prototype computerized structure-activity screening system. The system is currently used to estimate water solubility, vapor pressure, adsorption coefficients, bioconcentration factors, acute toxicity, and a variety of properties based upon the structure of the chemical. The system is also linked to data bases that allow investigators immediate access to the scientific literature on the substance being investigated.

Of all of the toxicity tests, one of the most difficult and expensive is the test for teratology (the potential to induce birth defects in mammals). Recently, EPA scientists developed a simple, inexpensive test to screen and identify those compounds requiring further, more expensive tests in experimental animals. The cost of such a screening test is approximately $3,000, compared to $75,000 per compound for traditional tests. Thus far the test has shown excellent correlation with results obtained through the expensive testing procedures.

Other research findings may dramatically improve efforts to deal with carcinogenic chemicals. Researchers from the Department of Defense, for example, have identified a chemical response within cells that gives an early indicator of the latent toxic effects associated with exposure to a cancer-causing chemical. It appears that carcinogenic chemicals induce the production of an enzyme (ADP-R synthetase) that can interfere with the cell's ability to repair damage to its DNA. Use of this indicator may greatly reduce the time and cost of current testing protocols. Related studies have demonstrated that benzamide compounds can prevent carcinogen-exposed cells from progressing to a cancerous state. Such findings are extremely significant in that they demonstrate a nongenetic mechanism for certain carcinogenic chemicals as well as a potential new compound to prevent cancer from being induced by these chemicals.

Hazardous Wastes

Approximately 50 million metric tons of hazardous wastes are generated per year. These wastes may be either stored in a structure or landfill, destroyed, or transformed into harmless substances.

Most natural and manmade chemical compounds are readily degraded by bacteria, yeast, molds, and other organisms in the environment. During the past few decades, however, certain new synthetic chemicals that are resistant to biodegradation have been introduced, causing serious environmental problems. Research is being conducted to develop biological mechanisms to selectively degrade toxic organic substances. Last year, researchers used a technique called plasmid-assisted biological breeding to develop a culture of microorganisms capable of breaking down the herbicide 2,4,5-T. The result was a mixed culture that would both survive in a 2,4,5-T solution and use that chemical as its sole food source. Further tests to determine if the organism can be used to dispose of 2,4,5-T outside the laboratory and whether the organism can also break down dioxin compounds will be conducted.

Concerned by the hundreds of abandoned hazardous waste sites throughout the country, Congress passed a law in 1980 creating a $1.6 billion fund (the Superfund) to clean up these sites. Because this is a new area of concern, State and local agencies involved in cleanup activities need the latest technical and scientific information. In 1982, EPA produced a document, "Remedial Action at Waste Disposal Sites," that contains extensive information on the subject to assist these agencies.

Environmental Protection Agency

A researcher in protective gear checks a monitoring station for evidence of possible toxic pollutants from a roadside chemical spill.

Radioactive Waste Management

The Nuclear Waste Bill passed in 1982 addresses the disposal of spent fuel from nuclear reactors. Extensive research is under way to determine the effectiveness of techniques for permanently isolating high-level wastes. One attractive method for storing high-level nuclear wastes involves encasing the wastes in glass. In 1982, Department of Energy researchers discovered that the leaching of plutonium from glass encasements depended strongly on chemically active leachates generated by the high radiation field in the water surrounding the glass containment. Other research, conducted by the National Academy of Sciences, indicates that ceramics may not be as susceptible to such leaching as glass.

In 1982, the Nuclear Regulatory Commission published final regulations for near-surface disposal of low-level wastes. Studies were initiated to assess risks associated with low-level waste facilities, and criteria were developed for the unrestricted disposal of materials containing very low levels of radioactivity.

Natural Forces

Natural forces—the climate, earthquakes, volcanic eruptions, landslides, and violent storms—significantly affect the quality of our environment. The responsibility for warning the public in the case of such natural geologic hazards rests with the U.S. Geological Survey (USGS). In 1982, research was conducted on how to improve hazard warning techniques and predictive information to local governments. Specifically, the USGS published revised volcano hazard reports for Mount Baker (Washington), Mount Hood (Oregon), and Mount Shasta (California). Mount St. Helens continues to be active and, in 1982, automated gas detection/analysis devices were installed to assist in monitoring it.

To improve severe storm warning capability, NOAA's National Weather Service and the National Aeronautics and Space Administration implemented a new Centralized Storm Information System. On April 2, 1982, the system was tested in the largest tornado outbreak in 8 years, when 90 tornadoes were reported over 16 states. The new system allowed rapid viewing and superimposing of satellite pictures for accurate storm visualization and tracking.

The Weather Service is providing alerts on flash flood warnings in small watersheds using river and rain gauges connected to home computers. Also, as a result of successful research adaptation in modeling of the atmosphere, global atmospheric wind and temperature forecasts can now be made to the aviation community. In addition, technology has provided accurate winter warnings for Florida citrus growers. Infrared satellite photos are combined with field observations to provide the warnings. In the winter of 1982, forecasters were able to correctly predict that the southern two-thirds of Florida would not suffer a threatened freeze, thereby saving growers the considerable expense of unnecessary protective measures.

Transportation is a key factor in U.S. society, and an efficient transportation system is a positive contribution to both economic and defense activities. The Nation's transportation system is largely mature. Most of the highways, railways, waterways, airways, and pipelines are in place; the vehicles and equipment have already undergone considerable development. Technological progress must concentrate principally on ways to make the existing system better, and the Federal responsibility is in providing a transportation system that is safer, more economical, more convenient, and less harmful to the environment.

Transportation research and development efforts in 1982 provided or improved the technology required to move ahead in a number of important areas. Among these achievements are:

- Completion of the first phase of a program leading to the implementation of an advanced system of air traffic control;
- Development of new effective methods to rehabilitate and preserve the Nation's highways and bridges; and
- Design of strategies to encourage seatbelt use and to prevent drunk driving in order to save lives on highways.

The following sections describe accomplishments in transportation system improvement, transportation safety, and transportation mission support.

Transportation System Improvement

The Department of Transportation (DOT) seeks to expand the knowledge base in a range of transportation areas. Problems being addressed by research efforts are transportation energy conservation, improvements in goods movement, transportation and economic development, efficiency and productivity in transportation systems, and transportation safety.

Highway System

Much of the local rural road system was designed for traffic needs of the 1930s and 1940s. Major changes have taken place. Farm equipment and trucks are too wide and too heavy for many rural roads and bridges. Research is under way to evaluate several investment strategies for providing the necessary funds to reconstruct and maintain rural roads and bridge systems to accommodate the transportation needs of rural America.

Additional highway research has been conducted by the DOT Federal Highway Administration (FHWA) on the use of sulphlex, chemically modified sulfur, as a highway binder material to replace or supplement asphalt cement derived from petroleum. Seven construction projects, varying in length from approximately 600 to 8,000 feet, have been completed with generally satisfactory performance. Structural design methods, chemical quality control, and process design for manufacture of existing sulphlex test installations are being reviewed, and definitive applications will be recommended in fiscal year 1983.

Researchers are evaluating the use of calcium magnesium acetate (CMA) as a safe, noncorrosive deicing chemical. CMA is as effective a deicer as salt when used at equal or lower temperatures. During late 1983 and early 1984, CMA will be tested for environmental acceptability, ice melting ability, corrosiveness to highway structural materials, and manufacturing possibilities.

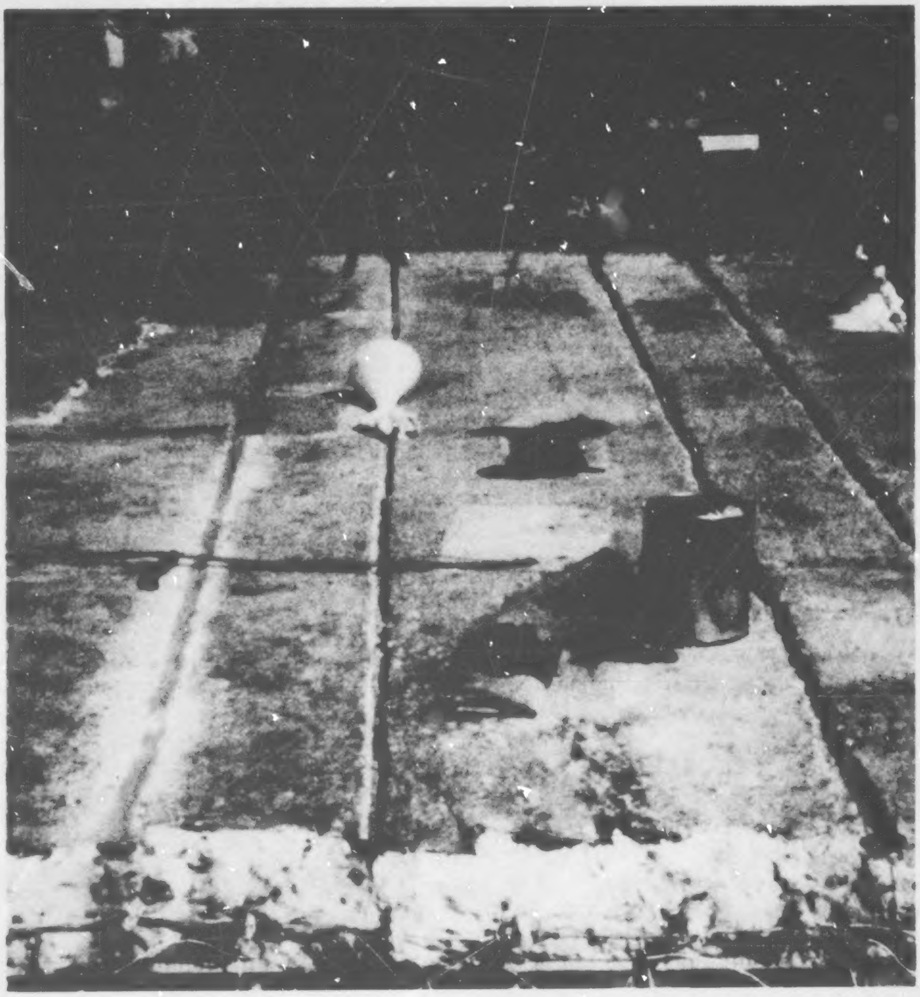
Bituminous overlays are a common rehabilitation procedure for high traffic concrete pavements, where premature failure can be catastrophic. There have been recent incidences of stripping and permanent deformation failures in these overlays. A research program is aimed at determining general relationships among the various roadway parameters and developing a method that can be used to calculate the stresses and strains at critical points for an overlay. This will provide criteria for producing improved mixes matched to local highway conditions.

Another research effort has centered on an economical cathodic protection (CP) system to prevent corrosion of the reinforcing steel in bridge decks. A CP system in which impressed current is applied to the reinforcing system is the only economical, proven process to stop the corrosion and eliminate the resulting delaminations, cracks, and spalls in the concrete of highway bridges. The weak point of previous attempts to retrofit CP systems has been the conductive medium to distribute the current over the surface of the bridge deck. An electrically conductive polymer grout material that is relatively easy to place and is conductive enough to eliminate the need for most of the platinum wire connectors used in other CP systems has been developed. During 1982, the CP system was installed on several bridge decks on an experimental basis for field evaluation.

Also in bridge research, a study has been started to define the fatigue resistance of full-scale riveted built-up members in their weathered and deteriorated state. Bridge engineers are in need of this information to form judgments on the safety and lifetime of thousands of spans in existence on highways, railroads, and mass transit systems.

Marine System

The Maritime Administration supported the development of contrarotating propellers for oceangoing vessels, which can improve



Department of Transportation

A new economical cathodic protection system prevents corrosion of the reinforcing steel in bridge decks.

fuel efficiency by 8 to 14 percent. Also being developed are tandem propellers (two propellers affixed to the same shaft that rotate together) that could achieve some of the savings of contrarotation at significantly lower costs. Propulsive improvements of 6 to 8 percent are predicted.

U.S. shipbuilding productivity is significantly below world standards. The Maritime Administration, together with the industry, has supported a program to revamp U.S. shipyard technology and the entire U.S. shipbuilding process. Where appropriate, new techniques are being imported from other countries. For example, a new automated shop now coming on line will reduce pipe fabrication manhours by 40 percent. This represents a substantial time savings, as piping for one ship now consumes nearly 200,000 manhours.

Land and Sea Navigation

The Coast Guard, the Department of Transportation, and the National Aeronautics and Space Administration are investigating new satellite systems, such as the Department of Defense's NAVSTAR Global Positioning System (GPS), to increase the safety and efficiency of transportation. NAVSTAR GPS is a constellation of 18 Earth-orbiting satellites that can provide worldwide navigational coverage. Civil users of airborne, land-based, and maritime vehicles will benefit from NAVSTAR GPS for optimal course navigation, which will in turn reduce fuel costs and transportation time. Land and water search and rescue techniques also may be enhanced via the Search and Rescue Satellite (SARSAT) module, scheduled for launch in 1983 as part of a National Oceanic and Atmospheric Administration weather satellite. SARSAT offers worldwide coverage and consistent accuracy.

Transportation Safety

Research and development were conducted to improve safety in all modes of transportation.

Automotive Safety

In experimental settings, the National Highway Traffic Safety Administration (NHTSA) actively promoted the use of automobile safety belts through various methods including prizes and awareness sessions. Long-term safety belt use was doubled in some cases, offering the prospect of significant lifesaving.

Automobile accident statistics reveal that up to 50 percent of all automobile fatalities are alcohol-related. To address this serious problem, the President in 1982 established the Commission on Drunk Driving to study alternative deterrence, enforcement, and educational drunk driving countermeasures.

A large portion of pedestrian impact trauma is produced by direct impacts to the lower body, knee, and legs by vehicle bumpers. Researchers are exploring soft bumper systems that are lower in weight, retain the low-speed, no-damage capabilities of current systems, and considerably mitigate the impact injury hazard to the pedestrian.

Aviation Safety

Approximately 20 percent of all general aviation aircraft accidents are weather-related. The seriousness of the problem and the prospect of increasing general aviation activity have resulted in an initiative to improve the timeliness and accuracy of weather information provided to air crews and air traffic controllers.

A new weather radar is being developed to replace the existing National Weather Service radars. The new radar will provide more accurate hazardous weather information to aviation users, including information on precipitation, wind velocity, and turbulence indications.

Ground-based automatic weather observations at airports will be transmitted to pilots and provided to flight service specialists, meteorologists, and air traffic controllers to improve safety and meet user demands. Demonstration of alternative automatic weather observation systems will begin in 1983.

Rail Transportation Safety

Research is directed toward reducing catastrophic railroad accidents and resulting fatalities and injuries to railroad employees and the public, and toward improving track structures and track defect detection.

Many derailments are caused by running rail cars of about the same length as the rail segments over jointed rail track. In 1982, the Federal Railroad Administration (FRA) developed and tested a cross-level index measuring device based on a gyroscopic system originally developed by the aerospace industry. The device is designed to be bolted to a locomotive axle, avoiding the need for a sophisticated track geometry measuring car. This development is part of a multiyear project to define safety performance specifications for track structure to reduce track/vehicle interaction derailments.

A test is in progress to determine the rate of rail flaw growth under traffic. A special rail flaw inspection device that permits repeatable mapping of the rail flaw using ultrasonic probes was successfully tested in the laboratory during 1982. Preliminary testing has also been started on a portable device to evaluate the track's ability to handle train loads without dynamic gauge widening. If the device achieves a good correlation with actual train induced load/deflection characteristics, it will greatly simplify evaluation of safe track strength.

Pipeline Safety

To improve the safety and productivity of natural gas and liquid oil transportation, DOT is studying the application of fracture mechanics technology to detect pipeline flaws. The research includes analysis of ductile tearing instability, fatigue, and corrosion fatigue. Mathematical models to predict critical defect sizes through analytically determined values of crack opening displacement and crack tip opening displacement are being developed.

Transportation Mission Support

The Federal Government provides essential operating services to air and water transportation through the Federal Aviation Administration (FAA), the Coast Guard, the Corps of Engineers, and the St. Lawrence Seaway Corporation. In addition, the Federal Government provides funding to State and local governments for such transportation facilities as airports, highways, and mass transit. Some R&D activities are intended to improve the technology associated with these services.

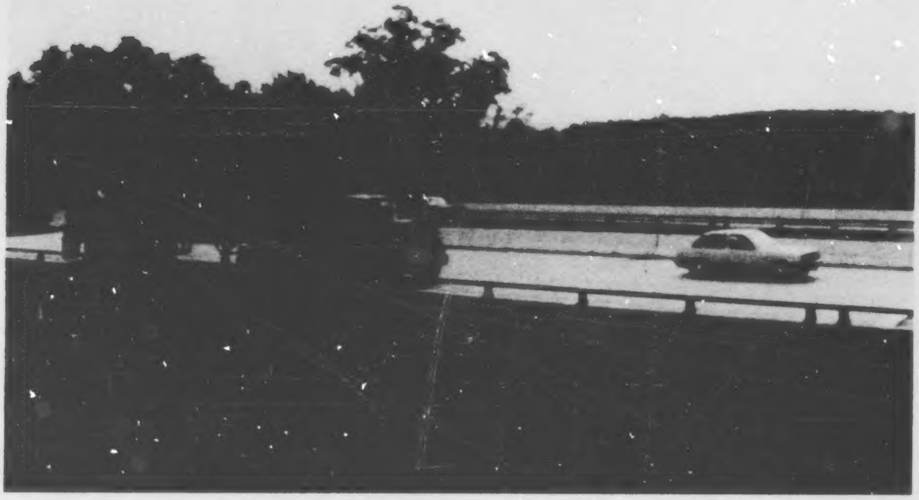
Highway Support

Vehicle weight data are essential for determining structural and maintenance requirements of bridges and pavements. Each year, substantial money and effort are expended to gather such data, and the adequacy of the data is questionable because of the ease with which overweight vehicles can bypass weighing sites. In addition, delays caused by traffic stopped for weighing have grown with increased traffic volume. One solution developed by FHWA in 1982 is a weigh-in-motion (WIM) instrumentation system that uses highway bridge structures as static scales to measure the weight of a vehicle crossing the structure at normal speed. The WIM system is self-contained and can be installed on a bridge in a few hours.

Traditional methods of sensing the flow of vehicles for traffic control or surveillance have used physically interconnected vehicle detectors. High installment costs and susceptibility to malfunctions due to pavement cracks, potholes, accidental breakage by construction crews, etc., make the detectors impractical. A new Self-Powered Vehicle Detector (SPVD) is designed to overcome these problems. When implanted below the roadway surface, the device detects a motor vehicle's magnetic field in a traffic lane. The buried SPVD sensor has an approximately 2-year operational life at the rate of 20,000 vehicles per day. Because it requires no interconnecting cable, the installation cost advantage is about three to one, and there is little probability of malfunction or breakage.

Aviation Support

In 1982, FAA initiated a program to modernize the existing air traffic control computer system. The hardware and software now located at both en-route air traffic control centers and major terminals will be systematically replaced with advanced high-level



Department of Transportation

A new system uses bridges to weigh vehicles in motion.

computers to improve safety and to handle the projected growth in aviation traffic beyond the late 1980s. Many air traffic control functions now performed by controllers could be performed automatically by computers. The system will be designed to continuously accommodate changes in computer technology.

General Support

Some pioneering work has been done to establish fundamental system concepts for using machine vision in the control of vehicles and to make feasibility studies on the technologies involved. The objectives of this work have been to identify typical transportation situations, to determine the necessary type and number of sensors and the minimum data rates, and to evaluate algorithms necessary for various functions, such as collision avoidance, in diverse transportation systems.

Plain carbon steels containing 1 to 2 percent carbon are called ultra high carbon (UHC) steels. These steels are normally considered to be hard and brittle. Recent research on small UHC casting has shown that these steels can be made strong and tough by special thermal-mechanical processing treatments. They do not rely on scarce alloying additions, and they are also superformable, which means that they can be pressed into intricate shapes avoiding costly machining operations. Strong and ductile UHC steels based on this research could have a number of transportation applications.

United States agriculture remains unmatched in the world in its production capacity. Maintenance of that capacity will require sustained advances in scientific knowledge and technology, such as those that have traditionally been produced by the complex set of Federal, State, and private institutions that make up the American food and agricultural sciences system. The Reagan Administration is committed to improving the capabilities of that system to conduct excellent, pertinent, scientific research and to apply the results of that research to meeting the challenges facing American agriculture. In particular, the Administration has taken steps to focus greater attention on high-risk, long-term basic research in federally supported programs and to deemphasize commercial development projects. The Administration is also attempting to supplement and complement traditional block grants to the States for research of local and regional importance with project grants directed toward basic research of national priority and open to scientists from all qualified institutions.

Some major research accomplishments in agriculture in fiscal year 1982 were as follows:

- Sex-attractant pheromones have been identified and synthesized for five important agricultural pests. Sex pheromone components that can be used to cause cross-mating of cotton bollworms and tobacco budworms with fatal consequences for both insects have been identified.
- The first natural enemy of curly dock weed was found in Italy. New approaches to weed control are being developed through the use of fungus and other plant pathogens.
- Early-developing calf embryos were split and successfully implanted in surrogate mother cows to produce genetically identical twin calves. Identical twins are highly valued for research.
- Genes controlling the production of the enzyme hydrogenase, which exist in the most efficient strains of the nitrogen-fixing bacteria *Rhizobium Japoniam*, have been cloned and transferred to mutant bacteria strains that lack this capacity. This technology will allow increased nitrogen fixation in bacteria associated with clover and alfalfa.
- For the first time, whole fertile corn plants have been successfully regenerated from cell cultures through somatic embryogenesis. This technology has important application to other agronomically important plants and is a critical step that will allow genetic manipulation and engineering of crop plants at the cellular level.

Meeting future domestic and export needs in agriculture will depend largely on our ability to increase the level and efficiency of food production through scientific breakthroughs and technological developments in crop and animal production; conservation of valuable "input" resources such as land, water, and energy; and improvements in food processing, marketing, and distribution. At the same time, better sources of information to guide agricultural policy-making and worldwide collaboration to speed the transfer of knowledge are necessary. Recent accomplishments in all these areas are described in the following sections.

Department of Agriculture

Sex attractant pheromones caused this fatal mating of a female tobacco budworm moth with a male cotton bollworm moth.

New Research Areas

Advances in two new areas, genetic engineering and viroid research, are making major contributions in agriculture.

Genetic Engineering

Recent developments in genetic engineering and related biotechnologies have important and long-lasting implications for agriculture and for agricultural research. These techniques will permit the transfer of genetic materials across species barriers with increasing predictability and precision, providing researchers with tools to unravel and understand the genetic and biochemical basis for growth and development. Thus, new germplasm in plants and animals can and is being created, rare animal and plant gene products are being synthesized by bacteria, and new fundamental knowledge is accumulating rapidly. Applications in food and agriculture are now in progress and will soon be more widespread.

Molecular genetics provides the information base for genetic engineering. The precise chemical structure of many useful genes is being determined. As a result, defined gene segments will be carried from one species to another, but, equally important, defined segments of genetic material will serve as probes to locate or map genes on chromosomes. One great challenge is to identify useful genes in plants and animals for selective transfer or modification. Currently, several kinds of genes are being manipulated, including those responsible for seed storage protein, host response to biological or physical stress, and symbiotic nitrogen fixation.

Future emphasis will be on the identification of genes associated with salt and other stress tolerances; disease resistance; photosynthesis; metabolite synthesis and transport, partitioning, and storage; and increased lysine and protein content or other factors controlling nutritional qualities of food crops.

Progress in genetic engineering of insects and animals has been rapid. The microinjection of isolated genes into newly fertilized eggs and the recovery of modified animals (mice, for example) demonstrates the vast potential for the modification of farm animals. Precious animal hormones, whose gene compositions are known, can be cloned in bacteria and fed to farm animals to speed growth and development. Microinjection techniques with plants are more difficult and have not been fully tested, but the prospects are equally bright. An excellent example of genetic engineering in agriculture is the development, using recombinant DNA technologies, of a vaccine for foot and mouth disease. Its application is worldwide.

One great advantage of these techniques is that they provide experimental windows for understanding growth and development. Specific sites and compounds that profoundly affect animal growth, behavior, and productivity will be identified.

In vitro (tissue culture) techniques associated with, or required for, genetic engineering also provide methods, mutants, and markers for rapid and predictable germplasm development that would be improbable in classical genetics. These in vitro techniques combined with gene isolation and transfer techniques will be widely applied to agriculture. However, the applications require standard breeding procedures.

The principles underlying molecular genetic approaches are common to all living systems. Progress in applications to agriculture is the outgrowth of a very broad spectrum of biological research, and, thus, the science of molecular genetics and principles of genetic engineering apply to all biological systems in agriculture, from soil microbes, to pathogens, to plants, to animals.

Viroid Research

Viroids are responsible for a number of economically important diseases of crop plants. The nature of these diseases remained enigmatic until research sponsored by the U.S. Department of Agriculture (USDA) and the University of California at Riverside demonstrated that they are caused by infection with disease-causing agents fundamentally different from any known before. Viroids consist solely of a short strand of ribonucleic acid (RNA), which, in contrast to viruses, is not surrounded by a protective protein coat. How such small RNA molecules can spread among plants, divert their host plant's metabolism to their own reproduction, and in the process play havoc with the invaded plant's health are important and difficult questions.

Recent work has brought the answers to these questions within reach. Genetic engineering technology has been used to construct a double-stranded DNA that mirrors the complete structure of a specific viroid. By insertion into bacteria, this DNA can be produced in any desired amount. Use of the recombinant DNA as a molecular probe for the detection of viroid-related molecules in infected plants has led to a clearer understanding of the mechanism of viroid reproduction at the molecular level.

Of even greater consequence in understanding viroids and the diseases they cause is the very recent demonstration that the artificially produced recombinant DNA is infectious. Thus, plants into which such DNA has been introduced produce the specific viroid and display the characteristic symptoms of the viroid infection. It is now possible to chemically modify the recombinant DNA in various ways, to introduce such artificial mutants into plants, and to observe their effects on viroid reproduction and symptom expression. Such experiments will identify specific regions of the viroid strand that are essential for symptom production or viroid reproduction, making it possible to construct a genetic map of the viroid for the first time.

In addition to answering fundamental scientific questions raised by the existence of viroids, research has resulted in spinoffs that are immediately useful and practical in agriculture. A rapid and inexpensive, yet extremely sensitive and accurate, diagnostic test for the presence of viroids in plant material has been devised. The feasibility and reliability of the test have been demonstrated, and a test kit is now being developed in the private sector. Already, the test is being implemented worldwide for the detection of a specific viroid contamination of seed potatoes.

Crop Production and Protection

Agricultural scientists have made many outstanding breakthroughs in increasing crop production. But, it is becoming more and more difficult to increase crop productivity. Crop production per acre increased at an average annual rate of 3 percent from 1950 to 1965. From 1965 to 1979, that rate dropped to 2.1 percent. Therefore, much new research is directed toward the complexities of plants and how they grow, and what will help them grow more efficiently. Several initiatives in weed and pest control are noted below.

Weed Control

Researchers have been puzzled by why herbicides affect some plants and not others. Recent studies of the herbicide Propanial, used on rice, have isolated an enzyme that detoxifies the herbicide as it enters the cells of rice plants. This same enzyme is not active in pest weeds. Recently, scientists have succeeded in locating the enzyme in the plant and in purifying it for further study. This could lead to breeding and identifying plants best suited for weed control with particular herbicides. As the enzyme is studied, genetic engineering means may be found to add specific herbicide resistance to the cells of critically important crop plants.

Scientists in southern universities have developed an improved method for synthesizing large quantities of strigol, the potent, naturally occurring growth regulator that causes witchweed seeds to germinate. Thus, for the first time, researchers will have the opportunity to evaluate the usefulness of strigol in controlling witchweed under field conditions.

Pest Control

A cooperative Federal-State program—the Integrated Pest Management Program—has recently developed and demonstrated the technology to eliminate reproduction of the boll weevil in a geographically defined area. The combined use of diapause control methods, pheromone traps, sterile males, and an insect growth regulator eliminated the boll weevil in a 3-year trial. This has the potential for saving over $100 million annually.

North Carolina State University

A mature witchweed plant (on right) attached to the roots of a corn plant. Corn plants infected with witchweed shrivel and die before reaching maturity.

For over a decade, scientists have sought biological rather than chemical controls to suppress the gypsy moth, which defoliates North American deciduous trees. Although several potential predators and parasites have been identified and collected worldwide, the tiny *Apantales* wasp species from India appears to be the most promising biocontrol agent. Mass rearing in the United States provided millions of wasps for release in New Jersey and Pennsylvania during the gypsy moth's larvae stage in 1982. The Indian wasps, harmless to humans, animals, and beneficial American insects, deposit five or six eggs on each gypsy moth larva they contact. As the wasp eggs hatch, they parasitize the moth larvae and prevent metamorphosis into adult reproductive moths.

Studies of the defense mechanisms of potato and tomato leaves found that an insect attack releases a chemical compound from the wounded leaves that travels throughout the plant to unwounded leaves at the rate of 4-5 centimeters per hour. The compound then sets into motion the production and accumulation of inhibitors. Within 48 hours, the level of inhibitors rises from zero to over 2 percent of the protein of young leaves. Further knowledge of this process could lead to some radically new and different ways of protecting crop plants from insects.

Natural polymers of agricultural products have recently been found useful for encapsulating and slowly releasing pesticides, thus improving the efficiency of pest control. Encapsulated pesticide is not subject to the usual losses due to volatilization, is not destroyed by sunlight, and is not easily leached by water. The pesticide is suitable for use in conservation tillage systems and also protects the soil because it can be deposited on top of it rather than in it.

Animal Production and Protection

Diseases, pests, and other health hazards cut heavily into the potential of food animal production, an important part of the U.S. agricultural economy. Nearly 15 to 20 percent of food animals die before they reach the market. This loss is estimated at about $12 billion annually.

Scientists have recently developed a vaccine that is very useful in preventing calf scours, which kills an estimated 500,000 calves a year. The vaccine is given to pregnant cows and stimulates the production of colostral antibodies. These antibodies immunize the calf—through the calf's drinking of the colostrum—during its first week of life when it is most susceptible to the disease.

A new international initiative has resulted in a joint study between Texas A&M University and Australia's Commonwealth Scientific and Industrial Research Organization to evaluate dung-burying scarabs as biological control agents of several insect pests afflicting dairy and beef cattle. The loss in U.S. meat and milk production due to horn and face flies is estimated at $600 million annually. By denying these pests their favored breeding grounds, researchers hope to reduce significantly the pest populations.

Scientists have developed a unique double-cropping system for rice and crawfish. After autumn harvest, rice field waste is used to feed crawfish during the winter and spring. Double cropping with rice following crawfish in the second year cuts down on fuel consumption by about 30 percent, because traditional soil preparation is unnecessary. The crawfish keep weeds and grasses under control by eating them, thus lowering the need for weedicides. The new system prevents soil erosion and conserves water, with rains providing the water needed for the crawfish and the early rice season.

Agricultural Land and Water

Conserving land, water, and energy resources is of continuing concern to agriculture and to our society as a whole. Recent research on nitrogen resources and water is described below.

Nitrogen Resources

Nitrogen fertilizer, produced from natural gas, is a very important resource associated with the use of land and water. Several Federal and State cooperating agencies have joined in a nationwide program for nitrogen and tillage research. As a result, farmers across the United States now have the technology base necessary for using improved methods of soil management to increase the efficiency of fertilizer, water, and fuel use; to control soil erosion; and to reduce environmental degradation.

It is estimated that half the nitrogen fertilizer put on crops is never found in the crop. This past year, scientists have found that most nitrogen is lost from surface soil, most loss occurs after rains, and most is lost from poorly drained soils. Such findings will be combined with information about soil characteristics, rainfall, and soluble carbon supply to predict nitrogen loss under given conditions. This should lead to more precise fertilization practices for different soils and different tillage conditions.

During the past year, scientists developed more efficient ways of determining fertilizer needs. Use of a nitrate nitrogen test of deep soil samples is saving corn growers $7.2 million annually in nitrogen fertilizer costs. It also means associated savings in the amount of natural gas needed to manufacture the fertilizer.

A 4-year study comparing conservation tillage with conventional tillage for corn-silage production was recently completed. Crop yields, nitrogen uptake from soil and fertilizer, and percentage of nitrogen-fertilizer recovery were greater under conservation tillage during years of drought. This could result in a savings of several million dollars in drought-prone areas.

Water Resources

Agricultural water is the single most limiting resource to crop production. During the past year, researchers developed a precise way of making hourly and daily evapotranspiration estimates from crops in the field. Using this method, scientists can study much more precisely the rate of water use on irrigated fields, as well as water consumption in natural plant communities. This will aid in finding ways to irrigate cropland more precisely and to predict plant growth and development in range and forest lands.

Timely control and distribution of irrigation water are critical to conservation. In 1982, a low-cost, automatic furrow-irrigation system for transporting and distributing water was demonstrated. The system is unique in that it has a single pipeline (a common plastic irrigation pipe) and provides for low-cost, automatic control of water to individual furrows via a moving plug operated by a battery-powered motor.

An economic and energy analysis of irrigation systems was started this year between the United States and Israel. The study will assess the extent to which water-saving irrigation technologies result in the substitution of energy for labor and water in arid environments of the Western United States and Israel. Research results will make it possible to evaluate the long-term energy implications of agricultural water resource development and changes in irrigation technology.

Processing, Marketing, and Distribution

Development of new knowledge and new technology in agriculture must extend beyond production of food and fiber to provide suitably processed food products.

Food Preservation

Federal scientists have developed several new techniques to preserve food products. For example, an electronic instrument continuously monitors the "breathing" of stored potatoes and detects abnormalities resulting from bacterial soft rot (for example, abnormal amounts of acetone, alcohol, and ketones). Early soft rot detection is expected to reduce by at least 20 percent the 400- to 700-million-pound loss currently suffered by growers.

A frozen milk concentrate to be marketed like frozen orange juice has been perfected. The reconstituted product tastes like fresh milk and offers reduced shipping costs, longer storage life, and less waste from spoilage. Manufacture of frozen lactose-free milk is also possible.

Scientists are trying to predict more precisely the shelf-life of processed foods. By testing unpackaged products under constant high temperatures and humidities, they have recently developed simple mathematical models that can be used to predict accurately quality change in any variable environmental condition. This will give grocers a better basis for use-dating foods, significantly improving the quality of food products on the shelves.

Insects infesting stored grain destroy millions of tons of the world's food supply. Rapid insect reproduction rates enable many pest species to develop tolerance to insecticides over a few years. A joint U.S. and Yugoslavian project has investigated the use of special inert dusts as possible alternatives to costlier and riskier chemical treatments for insect pests in stored grain. Inert dusts are fine enough to suffocate even the smallest insect.

Food Transportation

The frozen food industry is witnessing a gradual decline in the number of mechanically refrigerated cars operated by railroads. Accordingly, the American Frozen Food Institute, in cooperation with related industries and USDA, has a program under way to replace the diesel-powered mechanically refrigerated car with a cryogenically refrigerated car. Phase I, completed this year, indicated that spraying carbon dioxide (CO_2) snow over the top of the load in a conventional car would be practical. In Phase II, a prototype car with onboard CO_2 tanks and a temperature controlled spray system will be built. Industry is financing the cost of the car, while Government researchers will monitor test shipments over the next 2 years.

Information Needs in Agricultural Policymaking

Many environmental and economic events affect agriculture. Advanced knowledge of these events and a better understanding of how they influence food supply and demand may contribute to the development or reformulation of agricultural policies.

During 1982, USDA continued extensive efforts to develop applications of aerospace remotely sensed data to meet high-priority information needs in agriculture and renewable resources. An interdepartmental venture with the National Aeronautics and Space Administration and the Departments of Commerce and the Interior is designed to determine the usefulness, cost, and extent to which aerospace remote sensing data can be integrated into existing or future USDA systems. Such data will improve the objectivity, reliability, timeliness, and adequacy of information required to carry out USDA missions.

The AgRISTARS remote sensing system is the "focal point" of remote sensing research for application to global vegetation assessments. Recent accomplishments include development of new area sampling frames using Landsat imagery for more current stratification of land use, and continued improvement of methods to detect stress change in crops using Landsat and environmental satellite data.

International Collaboration in Agriculture

The Consultative Group on International Agricultural Research (CGIAR) is an informal group of bilateral and international donors dedicated to putting modern agricultural science at the service of low-income, food-deficient countries. The United States, through the Agency for International Development (AID), provides 25 percent of the core budget of the CGIAR centers. In 1982, this was just over $40 million.

A major advance has been made at one of the centers, the International Institute for Tropical Agriculture (IITA), in developing very early maturing cowpeas for rainfall-short areas of Africa. The varieties, which mature within 65 days and yield 1.5 tons or more per hectare, permit African farmers to produce two cowpea crops instead of a single crop.

Cassava, the source of tapioca, has now become the third most important energy food for 400 million people in the tropics. Serious insect pests such as mealybugs attack cassava, especially in Africa where 40 percent of the world crop is grown. Because of high costs and widely scattered small farms, chemical pest control is difficult. Biological control using two of the four natural predators of the mealybug introduced into Africa by IITA shows early promise of success.

Also, IITA has designed an improved intercropping system, called "alley cropping," which allows annual food crops to be grown in strips between rows of *leucaena*, a shrub or tree that can be used as a windbreak, as green manure for food crops, and as firewood.

The magnitude and diversity of U.S. R&D resources make cooperation with the United States in science and technology at individual, institutional, and governmental levels attractive and important to scientists from other nations. Conversely, American scientists and engineers continue to reap substantial benefits from their participation in cooperative international projects. These benefits include the use of facilities available in foreign countries that are unmatched here, including new or superior scientific instrumentation; access to unique geographical settings and phenomena, which is particularly important in such fields as biology, the earth sciences, and ecology; and opportunities to collaborate with first-rate foreign scientists and engineers, to study novel research techniques and approaches, and, frequently, to assess significant unpublished data. More broadly, both the financial and the human resources available to U.S. science and engineering are augmented through international cooperation. This is particularly important in fields requiring complex and expensive facilities.

America's international science and technology programs have agendas that are as varied as the interests and capabilities of the U.S. science and engineering communities themselves. Over 30 Federal departments and agencies engage in or support some form of cooperative scientific work with foreign counterparts. Many such activities are conducted under umbrella bilateral agreements, of which there are currently 54 with 29 countries. Others are carried out under the auspices of multilateral organizations or with agencies within the United Nations.

The guidelines that shape the international components of the Reagan Administration's science and technology policy are substantially the same as those that apply to its purely domestic components. International cooperative programs supported by the Government must be consistent with the President's commitment to maintain fiscal responsibility in the public sector and enhance incentives for private sector investment. They must be characterized, on the U.S. side, by a clear distinction between appropriate public and private sector roles. International research projects will be subject to criteria of excellence and mutuality of benefit. International applied research projects will also be subject to the criterion of pertinence to national economic and social goals and needs.

Applications of these policy guidelines for any given cooperative program depend on the specific concerns that the United States shares with the country involved and on that country's science and technology policies, resources, and capabilities. The industrialized democracies share concerns about sustained economic growth, improved environmental quality, and enhanced national security, for example. Hence, in those cases, the emphasis of the Reagan Administration's policy is on sharing R&D resources to maximize the return on investments to all cooperating parties.

The U.S. policy with respect to cooperation with the less developed countries is emphasizing the development of indigenous policies and capabilities for conducting scientific and technological activities and for applying those capabilities to the solution of urgent internal problems, particularly those of food, energy, natural resources, and health. This approach is designed to enable the less developed countries to enjoy a greater degree of self-reliance in applying science and technology to their current and future national problems.

Bilateral programs with a few selected countries, including India, Brazil, and the People's Republic of China (P.R.C.) have been singled out for special emphasis by the Reagan Administration, both because the scientific capabilities of these countries are already sufficiently advanced in some areas to permit fruitful cooperation with the United States, and because such scientific cooperation can promote foreign policy objectives that the Administration regards as particularly important.

In addition to programs involving cooperation between U.S. scientists and engineers and their colleagues in one or a few other countries, the Reagan Administration has been active in promoting the application of U.S. capabilities to help define and resolve problems of transnational concern, such as those associated with international telecommunications, the oceans, health, and natural resources.

Examples of these various types of international cooperative science and technology programs are discussed in the remainder of this section.

Cooperation with the Industrialized Democracies

Space Science

Space remains a preeminent area for international cooperation, particularly among the industrialized democracies. For its first operational flight, launched November 11, 1982, the Space Shuttle demonstrated a key capability by launching geosynchronous communications satellites belonging to Telesat Canada and Satellite Business Systems of the United States. These two launches are the forerunners of more than 70 communications satellites manifested for flight on the Space Shuttle through 1987, including those for Indonesia, Mexico, Australia, and India.

During the fourth test flight, successful engineering tests were conducted on a continuous flow electrophoresis system built by U.S. private industry, which may prove to be the prototype for a generation of space

National Aeronautics and Space Administration

The Satellite Business System (SBS-3) spacecraft springs from its protective "cradle" in the cargo bay of the Space Shuttle Columbia and heads toward a series of maneuvers that will eventually place it in a geosynchronous orbit.

manufacturing and processing facilities serviced by the Space Shuttle.

There is also foreign interest in materials processing in space. In June 1982, the European Space Agency (ESA) reserved a flight on the Shuttle in April 1987 for its European Retrievable Carrier (EURECA), to demonstrate the utility of such a platform for space processing and other applications late in the decade.

Preparations for the first flight of the Spacelab in September 1983 also gained momentum during the year. Spacelab was built at a cost of almost $1 billion by ESA. The first flight is a joint effort with U.S. and European experiments. The delivery of the first set of Spacelab flight hardware continued during 1982.

Two notable cooperative projects in space science were the following:

(1) The Infrared Astronomical Satellite (IRAS) launched in January 1983 is an international program with participation of the United States, the Netherlands, and the United Kingdom. The objective of IRAS is to conduct an all-sky survey and additional observations of infrared astronomical sources with a primary focus on extraplanetary, galactic, and extragalactic infrared objects. The Netherlands built the spacecraft, the United States provided the infrared telescope, and the United Kingdom is responsible for the tracking and data analysis. The IRAS mission will provide a wealth of material for an initial survey of regions of active star formation as well as the brightest extragalactic sources.

(2) A Memorandum of Understanding was signed between the United States and West Germany for a joint project to design, develop, and operate an X-ray observatory to study X-ray emissions from nonsolar celestial objects from a German satellite to be launched in 1987.

Energy Research and Development

In the area of energy research and development, the United States is involved in four classes of cooperation under the auspices of the Nuclear Energy Agency (NEA), a technically oriented agency within the Organization for Economic Cooperation and Development (OECD) structure. These include uranium enrichment, radioactive waste management, nuclear data and computer programs, and reactor decontamination. The United States is seeking to expand its role in the Agency's work and to focus increased NEA attention on the broader technical policy problems associated with nuclear energy development. These include a wide range of economic and energy policy issues that increasingly are affecting national decisionmaking.

Scientists in the United States are also engaged in energy research and development projects under the terms of specific bilateral agreements. For example, American and German scientists have initiated cooperative exchange activities in the area of biomass energy conversion. In both the United States and Western Europe, biomass energy may play an important role in meeting future energy needs. Similar cooperative exchange initiatives were implemented during the past year with Japan, where heavy dependence on imported fossil fuels makes the search for alternative energy sources a high priority.

Progress was also made in 1982 in the long-term cooperative program with the Japanese on magnetic fusion research and development. This program is the most extensive activity under the 1959 U.S.-Japan Agreement on Research and Development in Energy and Related Fields. At present it includes personnel exchanges, joint planning for complementary experimental projects, support of a joint Institute of Fusion Theory, a Rotating Target Neutron Source facility, and cooperative efforts to upgrade the Doublet III tokamak, which, when completed, will make that device the world's largest operating device of its kind.

General Science and Technology

Considerable multilateral cooperation in science and technology among industrialized democracies occurs under the auspices of the North Atlantic Treaty Organization (NATO) and the OECD. In addition, the Versailles Summit in 1982 initiated a working group on science and technology, as discussed in detail in Chapter I.

The NATO Science Committee has continued its programs of support for interaction between active scientific research personnel of the alliance. The Committee has established survey groups, made up of high-level scientists with wide-ranging interests, to propose topics for new special programs under the International Scientific Exchange Program. The goal is the identification of areas in which the promise and the current state of development warrant extra efforts to accelerate their progress.

The Science Committee also conducted forum discussions on critical points of science. Recent forum topics have included the international mobility of scientists, the interaction between industrial and public research, the problem of maintaining research excellence, and the benefits and limitations of bilateral and multilateral cooperative science programs.

An OECD symposium on International Cooperation in Research and Development will be hosted by the Japanese Government in Tokyo in the fall of 1983. Three themes will be examined by working groups: mechanisms of international cooperation in basic research, international cooperation in applied research, and cooperation between countries with differing economic scale and technological levels.

The Road Research Program (RRP), a technically oriented agency within OECD, accomplishes its objectives through a triennial program of research activities and the International Road Research Documentation (IRRD) Program, a cooperative computerized scheme for the systematic exchange of scientific and technical literature of member countries. The general themes for the 1983-1985 program of activities include research on the assessment of road transport strategies, concepts and methodologies for integrated safety programs, and the preservation, rehabilitation, and construction of road infrastructures.

In addition to large-scale cooperative programs carried out under the auspices of formal intergovernmental agreements, individual U.S. scientists and engineers continued, in 1982, to participate in a wide range of basic research activities, supported in part by Federal research grants, that involved some measure of interaction with foreign scientists and engineers. These activities ranged from travel abroad to participate in international scientific meetings or to consult about collaborative research projects, to longer term research work at such foreign laboratories as the European Center for Nuclear Research (CERN) in Geneva. American scientists were also engaged in research programs involving colleagues from several nations in such fields as ocean and atmospheric sciences, in which global data collection and analysis have been proceeding for several years. Collaborative earth sciences studies in Antarctica are a particularly significant group of projects in this category.

Cooperation with the Less Developed Countries

The primary goals of U.S. cooperative science and technology programs with the less developed countries are to help those countries build their own capabilities in science and technology so that they can solve many of their own developmental problems, and also to enhance their access to the scientific resources available in the industrialized democracies, particularly the United States. The Nation's science also benefits directly from these cooperative programs. Many less developed countries offer opportunities for research in the fields of biology, geology, and medicine, for example, that are unavailable in the industrialized countries. Moreover, the United States can gain substantially from economic development in the poorer countries. For example, the increased grain yields from improved crop varieties developed at U.S.-assisted international centers have the potential to increase significantly agricultural productivity in the United States. Likewise, the development of conventional and renewable energy resources in the less developed countries has the potential to reduce the pressure on dwindling world oil supplies and thus to improve world energy security.

Specific examples of current, high-priority cooperative programs involving scientists from the United States and less developed countries (in addition to those highlighted in Chapter I) are described in the following paragraphs.

Agricultural Research

U.S. support continues for 15 international agricultural research centers and programs, many of which have made significant contributions to world agriculture. For example, in 1982, more than 80 percent of the rice planted in Indonesia was a result of modern rice technology, stimulated by U.S.-funded cooperation between Indonesia and the International Rice Research Institute in the Philippines. Equally impressive U.S.-assisted progress has been made in India and Pakistan. Both countries are nearly self-sufficient in wheat production as a direct outcome of collaborative work with the International Center for the Improvement of Maize and Wheat and the building of national research capability.

Also in agricultural research, considerable emphasis is being placed on efforts to reduce the amount of energy used in food production. In addition to work on photosynthesis, which makes better use of the Sun's energy, and nitrogen fixation, which would reduce fertilizer requirements, scientists are working to increase fertilizer efficiency and to find better methods for drying grains.

Health Research

A major accomplishment in the health research field in 1982 was the establishment, in Egypt, of an epidemiology study center to conduct research on health problems such as diarrheal disease, control of schistosomiasis, studies on mycotoxins, the consequences of anemia in Egypt, and the training of Egyptian and U.S. health professionals.

Following up on understandings reached in 1981 under the bilateral health agreement with Nigeria, nursing and professional education and training teams visited a number of institutions in that country in April 1982 to assess specific health needs with respect to nursing and the training of medical and dental manpower. Recommendations regarding improvement of training programs and suggestions for Government of Nigeria action have been submitted to the Nigerian Federal Ministry of Health. Other activities under consideration are the establishment of a maximum containment laboratory for such activities as rapid diagnosis of viral agents of suspected haemorrhagic fever and sero-epidemiological surveillance; development of a health information system for Nigeria's Federal Ministry of Health; and improvement of immunization programs.

The bilateral health agreement with the People's Republic of China is one of the largest and most active formal cooperative health programs in which the United States is involved. An important milestone in 1982 was the publication of a special supplement to the *American Journal of Public Health* that presents the results of a joint U.S.-P.R.C. effort to study the health status, costs, and services in Shanghai County.

Earth Science Research

In the earth science field, U.S., British, and Indian scientists are engaged in a systematic study of the well-exposed sections of the Deccan basalts in Western Ghats, India. This research aims at a better understanding of the crucial role of basalt in the formation of the Earth's crust by partial melting of the mantle.

Also, U.S. and Mexican geologists in 1982 initiated studies of relationships among stratigraphic and structural conditions and mineral deposits in the Mexican states of Baja California and Sonora, and they also initiated preparation of a metallogenic map of the Western Cordillera and Coast Range. The results of these activities will be useful in mineralogical explorations of analogous geological areas in the United States.

Cooperation with India, Brazil, and the People's Republic of China

The Reagan Administration has assigned a particularly high priority to bilateral scientific cooperative programs with India, Brazil, and the People's Republic of China.

Scientific cooperation with India was highlighted during a July 1982 visit to Washington of Prime Minister Gandhi, following which she and the President announced the formation of a joint senior scientific panel to formulate plans for intensified joint research efforts. A summary of the initiatives proposed as a result of that panel's deliberations appears in Chapter I.

Science and technology relations played an important role in the President's December 1982 visit to Brazil, and, as a result, the Working Group on Science and Technology was set up by the U.S. Department of State and the Brazilian Foreign Ministry. The overall objective of this working group is to renew the currently expiring intergovernmental science and technology agreement between the two countries. To advance these efforts, a conference on U.S.-Brazil private sector cooperation in science and technology was held in April 1983 to explore ways in which the intergovernmental agreement can advance industrial productivity in the two countries.

Scientific cooperation with the People's Republic of China is conducted under a joint umbrella agreement signed in 1979. Since that time, the two sides have concluded technical protocols on cooperation in 21 fields, including student/scholar exchange, agriculture, and space technology. (Protocols for 4 of these 21 were concluded in May 1983.) A Joint Commission directs and coordinates the overall program. The Chinese attach high importance to science and technology cooperation with the United States. They see the United States as the only country with a sufficiently large scientific base and resources to meet China's requirements on a broad front, especially its need to train technical personnel.

The student/scholar exchange program, now in its fourth academic year, continues to provide opportunities for advanced study and research in China for American graduate students and postdoctoral scholars in the natural and physical sciences, social sciences,

Bill Fitz-Patrick, the White House

President Reagan confers with Prime Minister Gandhi during her recent visit.

and humanities. Including those there now, over 200 American scholars and students have pursued study and research in China in a program supported by U.S. cooperating agencies and the private sector. An estimated 4,500 Chinese Government-sponsored students and scholars are now studying or doing research at U.S. institutions.

The scope of the cooperative basic sciences program was increased substantially in 1982 to cover the following additional scientific areas: earth sciences (geophysics and geochemistry); engineering sciences (fluid mechanics, heat transfer, and related areas of applied mathematics); information sciences (basic and theoretical research in such areas as artificial intelligence and pattern recognition); international relations; and plant studies. Eleven new research projects (some of 2 years' duration) were funded during the year, compared with seven the previous year. Costs are shared by the U.S. and Chinese Governments following joint approval of proposed projects. Joint approval mechanisms were also substantially improved in 1982.

In addition, support continued for the National Academy of Sciences' cooperative programs with China in the natural and engineering sciences. These programs include symposia and individual scientific exchange activities, in which the participation of roughly 50 scientists each year is supported by the United States.

In high-energy physics, the Chinese, after consulting closely with their U.S. counterparts, decided in November 1981 to build a 2.5 GeV (billion electron volt) by 2.5 GeV electron-positron colliding beam storage ring called BEPC (Beijing Electron-Positron Collider) in place of a previously planned 50 GeV proton synchrotron. U.S. scientists have contributed to the design of this project primarily through consultations and training. Given the history of Chinese success in particle theory, the U.S. Department of Energy expects to gain from the Chinese fresh and original ideas and insights into the nature of matter and new directions to explore.

The U.S.-P.R.C. Protocol in health sciences represents one of the largest and most active formal cooperative health programs in which this country is engaged. During 1982, the United States hosted the third meeting of the Joint Health Committee, during which the progress and future plans for research and exchange visits in the agreed areas of cooperation (including cancer, cardiovascular disease, public health, and immunology) were reviewed. Approval was given to a broad range of studies, including continuation and expansion of several epidemiological studies in cardiovascular disease, cancer, and communicable diseases.

Continued expansion of cooperation between the United States and the P.R.C. in agricultural sciences also occurred during 1982. This was particularly true of exchanges, with each country sending a dozen teams of scientists to visit the other. Two notable events were a major soybean symposium held in the United States, and the signing of a formal agreement to establish uniform standards for storage and handling of grain. Several long-term scientific studies were also begun on such topics as forestry, soil, and water; swine production; pomology; and biocontrol of the gypsy moth. As part of the last-mentioned study, the United States received 25 species of natural enemies of gypsy moths and expects to receive additional live specimens in 1983.

Transnational Scientific Cooperation

During 1982, U.S. capabilities in science and technology continued to be used to make significant contributions in areas of transnational interest, including international telecommunications, ocean studies, health science, and natural resources. Significant accomplishments included these:

(1) In March and September 1982, International Telecommunications Satellite Organization spacecraft (INTELSAT V) were successfully launched using U.S. Centaur vehicles. Additionally, the INTELSAT system was expanded to 166 countries and territories. Delivery of the first INTELSAT VI spacecraft is expected in 1986, with a capacity of 35,000 voice circuits and improved capability for domestic lease services. Significant

use of the Space Shuttle for launching the INTELSAT VI satellites is foreseen.

(2) The International Maritime Satellite Organization (INMARSAT) became operational February 1, 1982, when the commercial capacity of the U.S. MARISAT system was transferred to INMARSAT's control. In the past year, membership in the Organization has grown to 37 countries, and the space segment is now used by more than 1,450 ships and offshore structures. In May 1982, the MARECS—a spacecraft manufactured by the European Space Agency for use by INMARSAT—was successfully launched and is currently in service in the Atlantic Ocean region. The global INMARSAT system also includes MARISAT spacecraft in the Pacific and Indian Ocean regions, and will be complemented by maritime payloads on board four INTELSAT V spacecraft, the first of which is expected to be in service in 1983.

(3) At its November 1982 meeting, the Intergovernmental Oceanographic Commission (IOC)—a semi-autonomous organization within UNESCO—adopted the program entitled "Ocean Science in Relation to Living Resources" as one of its major formal programs. The concept of such a program had earlier been suggested by the United States. It will entail major oceanographic studies concerning the interrelationship between the marine environment and the living resources within that environment. For coastal developing nations, the program will enhance their capability to manage fishery resources. For the United States, which has the single largest fishery resource of any nation, the fundamental knowledge gained through this program should be of great benefit.

(4) The year 1982 also witnessed continued activity in the International Program for Ocean Drilling, supported primarily by the United States with additional financial assistance provided by the Federal Republic of Germany, France, Japan, and the United Kingdom. The purpose of the program is to understand the nature of the oceanic crust and the evolution of the ocean basins by means of sediment cores obtained at sites both in the open ocean and on the continental margins. The foreign participants in the program have benefited from sharing in its execution and results, while the United States has also benefited through the sharing of scientific expertise, particularly with regard to regional data on potential drill sites.

(5) During 1982, the United States continued its active participation in the work of the World Health Organization (WHO). At the 35th World Health Assembly, the United States pledged continued support to the organization and to its goal of "Health for All by the Year 2000". A Plan of Action for implementing, monitoring, and evaluating the global strategy for Health for All, including a timetable complementing the WHO Seventh General Program of Work (1984-1989), was adopted. The plan spells out what is expected of member states, of WHO's governing bodies, and of the WHO Secretariat. In its focus on primary health care and community participation, the plan emphasizes the process of development as involving a grass roots approach and one in which all sectors of development, not only health, are involved. Emphasis is on strengthening indigenous health management and planning capacities.

(6) During the past few years, U.S. scientists have been engaged in collecting seeds and other forms of plant germplasm native to foreign countries and evaluating and testing them for their inherent desirable properties. Collecting and cataloging the germplasm of as many existing plant species as practicable is also regarded as imperative in view of mounting evidence that the world's genetic diversity is rapidly decreasing. Highlights of these activities during 1982 included: accession of over 500 varieties of forage grasses and legumes from the Soviet Union; study of Monterey Pine production in Chile; cooperation with Spanish scientists in developing tissue culture techniques to reduce viral attacks in fruit-tree seedlings; and collection of wheat-rust infected crops in Mexico to develop resistant strains of wheat.

APPENDIX

SPECIAL ANALYSIS K

RESEARCH AND DEVELOPMENT

The Budget of the United States Government, 1984

OFFICE OF MANAGEMENT AND BUDGET
EXECUTIVE OFFICE OF THE PRESIDENT
January 1983

Note.—All years referred to are fiscal years, unless otherwise noted. Details in the tables, text, and charts of this booklet may not add to totals because of rounding.

SPECIAL ANALYSIS K

RESEARCH AND DEVELOPMENT

This analysis covers the funding of research and development across all departments and agencies with R&D programs of $10 million or more, representing over 99% of total Federal funds for R&D. It consists of two sections. The first highlights the R&D policies and trends in the 1984 budget. The second describes in more detail the R&D programs of 13 agencies whose R&D obligations individually exceed $150 million.

PART I. HIGHLIGHTS

Total Federal funding for research and development, including R&D facilities, is proposed at $47.0 billion in 1984, an increase of $6.9 billion or 17% above the 1983 level of $40.1 billion. Included within the overall R&D funding is support for the conduct of basic research, estimated to increase by 10%, from $6.0 billion in 1983 to $6.6 billion in 1984, including an 18% increase in programs of the National Science Foundation.

The Federal Government funds R&D activities to serve two broad purposes:

- To meet specific Federal Government needs—where the principal user of the R&D is the Government itself—for example, to ensure a strong national defense;
- To meet broad national needs—where the Federal Government supports R&D that the private sector lacks incentive to invest in adequately, in the national interest—to help assure the strength of the economy and the quality of life for all people. Included in this category are, for example, agricultural and health research; support of basic research through programs of the National Science Foundation and the general science programs of the current Department of Energy; and the pursuit of selected long-term energy technologies, such as magnetic fusion.

The 1984 budget continues to reflect the established policies of the Administration in funding R&D but further strengthens support in areas of major Federal responsibility. It provides for:

- Major increases across all R&D programs of the Department of Defense;
- A significant increase in Government-wide support of basic research with emphasis on support of research in the physical

sciences and engineering. Advances in these fields are key to future national defense and the long term competitiveness of the U.S. economy, particularly in high technology industries.

- A number of major new initiatives, particularly in energy-related programs, currently in the Department of Energy, and in NASA that will significantly enhance the research productivity of the Nation's scientific community especially in basic research. These include a new center for materials research at the Lawrence Berkeley Laboratory, expansion of the National Synchrotron Light Source at Brookhaven National Laboratory, a new colliding beam facility at the Stanford Linear Accelerator Center, and a numerical aerodynamic simulation capability at NASA's Ames Research Laboratory.
- Continued reductions in Federal support of nearer-term R&D and demonstration programs (e.g., in energy technologies). For such programs the private sector, not the Federal Government, has the expertise and capability to select and fund the advancement of technologies that can be successfully brought into the marketplace. To complement private sector efforts, the Federal Government's role is primarily to create an economic climate conducive to private investments, through such measures as tax incentives and reductions in the burden of regulations. Federal Government investments should be limited to longer term research and technology support which the private sector does not have the economic incentive to provide for adequately to serve the national interest.

The Administration will further seek, in 1984, to make more effective use of increased research funds, particularly in the basic sciences to:

- Attract the highest caliber scientists and engineers, particularly young faculty members, into research and encourage and support them in their careers. These efforts will assist in ensuring a high quality scientific workforce to meet needs of the Nation both in the near and the long term;
- Encourage greater and more creative interaction among university, Government and industry scientists to bring the Nation's best scientific expertise together in addressing the most challenging scientific and technical problems and opportunities; and
- Upgrade the scientific instrumentation of universities to enhance productivity and excellence in research and the training of scientists and engineers.

The 1984 budget also includes proposed efforts by the NSF and the Department of Education to improve the teaching of science and mathematics in the Nation's secondary schools. Though not covered in this analysis, these efforts will help in improving the capability of the future work force to contribute to economic growth in an increasingly technological society.

Total obligations and outlays for the conduct of all Federal R&D programs and for related facilities are shown in Table K-1.

TABLE K-1. **TOTAL FEDERAL FUNDING FOR CONDUCT OF R&D AND RELATED FACILITIES**

(in billions of dollars)

	Obligations			Outlays		
	1982 actual	1983 estimate	1984 estimate	1982 actual	1983 estimate	1984 estimate
Conduct of R&D	36.4	38.9	45.8	34.5	37.7	42.7
R&D Facilities	1.2	1.2	1.2	1.3	1.2	1.1
Total	**37.6**	**40.1**	**47.0**	**35.8**	**38.9**	**43.8**

CONDUCT OF RESEARCH AND DEVELOPMENT

The 1984 budget includes $45.8 billion in obligations for the conduct of R&D, an increase of $6.9 billion or 18% over 1983. Highlights of the programs of the major R&D agencies that account for 93% of the proposed obligations for the conduct of R&D by all agencies are presented below:

- **Department of Defense (DOD).**—Obligations for the conduct of R&D by DOD are estimated at $29.9 billion in 1984, an increase of $6.7 billion or about 29% above 1983. This represents 65% of the total Federal funds for R&D proposed for 1984. The increased funds are proposed for R&D largely related to advanced strategic systems such as the Peacemaker and Trident II ballistic missiles. In addition, the Department would also provide for increased emphasis on basic research in such areas as materials and microelectronics, and advanced technology development in such areas as very high speed integrated circuits.
- **National Aeronautics and Space Administration (NASA).**—Obligations for the conduct of R&D by NASA are estimated at $2.5 billion in 1984, about equal to 1983. The 1984 request would allow NASA to pursue a vigorous program of space science, applications, and advanced technology for space projects and future aircraft. The 1984 budget proposes several new initiatives such as a Venus Radar Mapper to provide a map of the surface of Venus, a numerical aerodynamic simulation capability, and development of advanced composites for large aircraft structures. Previously approved projects such as the Space Telescope, and the Advanced Communications Technology Satellite (ACTS) will be continued.

- **Energy Related Activities.**[1]—Obligations for the conduct of R&D programs currently in the Department of Energy are estimated at $4.7 billion, about the same as in 1983. However, basic research funding would be increased by $160 million, or more than 18% over 1983. Increases are proposed to strengthen the nuclear weapons R&D program, to enhance support for long-term energy research, and to maintain a strong national basic science effort in high energy and nuclear physics. These increases are offset by proposed reductions in support for nearer-term energy technologies such as fossil and solar demonstrations, where reliance is placed on private sector support.
- **Department of Health and Human Services (HHS).**—Obligations for the conduct of R&D in HHS are proposed for an increase of $100 million, from $4.3 billion in 1983 to $4.4 billion in 1984. This represents a 12% increase over the two year period, 1982-1984. The National Institutes of Health (NIH) account for about 87% of total R&D funding by HHS. An increase of $71 million above 1983 is proposed for R&D programs of NIH, including basic research in the biomedical sciences.
- **National Science Foundation (NSF).**—R&D obligations by NSF are expected to increase by $180 million, or 17%—to $1.2 billion in 1984. The additional funds will largely be devoted to strenthening support of basic research in the mathematical and physical sciences and engineering, that support long-term economic growth. This increase also provides additional funds for upgrading research instrumentation at universities.

Table K-2 summarizes Federal support for the conduct of R&D by agency.

CONDUCT OF BASIC RESEARCH

The 1984 budget continues to reflect the Administration's view that investments in basic research across all scientific disciplines are critical to the long-term economic strength of the Nation and the well-being of its citizens. Basic research in such fields as mathematics, physics, chemistry, and engineering provides the foundation, in the long term, for a strong national defense, and leads to new discoveries and new technologies and industries that enhance U.S. competitiveness, employment and the quality of life.

Federal Government funding for the conduct of basic research is included within the total support for the conduct of R&D. In 1984, obligations for the conduct of basic research are estimated at $6.6 billion, an increase of $594 million or 10% above the 1983 level.

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[1] These programs, along with other activities currently funded by the Department of Energy, will be proposed for reassignment to other Executive departments and agencies

TABLE K-2. CONDUCT OF RESEARCH AND DEVELOPMENT BY MAJOR DEPARTMENTS AND AGENCIES

(In millions of dollars)

Department or agency	Obligations			Outlays		
	1982 actual	1983 estimate	1984 estimate	1982 actual	1983 estimate	1984 estimate
Defense-Military Functions	20,576	23,179	29,882	18,201	21,847	26,844
Energy Related Activities	4,758	4,712	4,713	4,974	5,012	4,911
Health and Human Services	3,935	4,316	4,416	3,978	4,262	4,339
(National Institutes of Health)	(3,432)	(3,771)	(3,842)	(3,438)	(3,737)	(3,808)
National Aeronautics and Space Administration	3,084	2,506	2,473	3,220	2,386	2,421
National Science Foundation	975	1,060	1,240	1,014	1,002	1,137
Agriculture	798	850	849	808	839	848
Transportation	309	393	519	349	376	451
Interior	381	373	329	392	411	348
Commerce	290	312	227	285	315	249
Environmental Protection Agency	335	241	208	336	295	250
Nuclear Regulatory Commission	221	210	200	209	210	200
Veterans Administration	140	165	163	138	157	156
Agency for International Development	165	152	161	179	200	152
All other [1]	388	391	418	426	425	433
Total	**36,354**	**38,860**	**45,796**	**34,509**	**37,735**	**42,741**

[1] Includes the Departments of Education, Justice, Labor, Housing and Urban Development and Treasury, the Tennessee Valley Authority, the Smithsonian Institution, the Corps of Engineers, and the Federal Emergency Management Agency.

This increase will result in a "real" growth in the Government-wide support of basic research of more than 4% above 1983.

For agencies primarily supporting basic reasearch in the physical and engineering sciences, particularly DOD, NASA, NSF, and including the energy-related programs currently under DOE, the increase in 1984 will be 15% over 1983.

Support for basic research in the life sciences, particularly in NIH, has been growing significantly in recent years. The Administration is seeking, through emphasis on the physical and engineering sciences in the 1984 budget, to balance Federal support of basic research across all major disciplines.

Enhanced support of basic research will further strengthen the scientific capability of the Nation's universities whose researchers receive about half of the total Federal obligations for basic research and conduct about half of all basic research performed in the Nation.

Table K-3 summarizes Federal support for the conduct of basic research by agency.

Table K-3. **CONDUCT OF BASIC RESEARCH BY MAJOR DEPARTMENTS AND AGENCIES**

(In millions of dollars)[1]

Department or agency	Obligations			Outlays		
	1982 actual	1983 estimate	1984 estimate	1982 actual	1983 estimate	1984 estimate
Agencies supporting primarily physical sciences and engineering:[2]						
National Science Foundation	916	998	1,181	954	943	1,083
Energy Related Activities	777	861	1,021	774	859	1,001
Defense—Military Functions	686	769	867	603	746	776
National Aeronautics and Space Administration	538	605	682	537	588	658
Interior	74	80	89	74	89	94
Commerce	17	18	16	16	16	17
Other Agencies[3]	9	7	8	9	7	8
Subtotal	3,017	3,347	3,864	2,967	3,249	3,636
Agencies supporting primarily life and other sciences:[4]						
Health and Human Services	1,953	2,184	2,238	1,962	2,154	2,214
(National Institutes of Health)	(1,840)	(2,049)	(2,086)	(1,835)	(2,022)	(2,068)
Agriculture	331	362	381	338	356	380
Smithsonian Institution	55	60	68	47	60	62
Environmental Protection Agency	33	21	17	30	25	22
Veterans Administration	13	15	15	13	15	15
Education	16	16	14	22	22	18
Other Agencies[5]	22	22	22	22	23	13
Subtotal	2,422	2,678	2,755	2,434	2,655	2,723
Total	5,439	6,025	6,619	5,401	5,904	6,359

[1] Amounts reported in this table are included in totals for conduct of R&D.

[2] Includes mathematics and computer sciences.

[3] Includes the Corps of Engineers, the Federal Emergency Management Agency, the Tennessee Valley Authority, and the Department of Transportation.

[4] Includes psychology and social sciences.

[5] Includes the Departments of Labor, Justice, and Treasury, and the Agency for International Development.

R&D FACILITIES

Excellence in research and development requires the availability of modern facilities and equipment. Additional funding for research equipment and instrumentation is included in support for the conduct of R&D including basic research. Funds identified separately by Federal departments and agencies for R&D facilities are summarized in Table K-4.

Obligations for R&D facilities, which include primarily construction or renovation of general purpose laboratories and research support facilities, would decrease by $54 million, to $1,195 million in 1984.

Trends in the funding of R&D facilities generally reflect program directions in agency support for the conduct of R&D as described below.

Table K-4. **RESEARCH AND DEVELOPMENT FACILITIES BY MAJOR DEPARTMENTS AND AGENCIES**

(In millions of dollars)

Department or agency	Obligations			Outlays		
	1982 actual	1983 estimate	1984 estimate	1982 actual	1983 estimate	1984 estimate
Energy Related Activities	762	619	501	804	623	532
Defense—Military Functions	290	323	438	232	289	349
National Aeronautics and Space Administration	92	160	156	109	136	129
Health and Human Services	29	60	29	38	31	35
(National Institutes of Health)	(20)	(21)	(26)	(35)	(20)	(20)
Agriculture	30	38	26	30	45	22
All other [1]	30	49	45	40	34	48
Total	**1,234**	**1,249**	**1,195**	**1,253**	**1,158**	**1,114**

[1] Includes the Departments of Transportation, Commerce, Interior, and Treasury, the Agency for International Development, Veterans Administration, Tennessee Valley Authority, Smithsonian Institution and the National Science Foundation.

PART II. AGENCY R&D PROGRAMS

Presented below are summaries of the R&D activities of the 13 agencies whose R&D obligations individually exceed $150 million.

DEPARTMENT OF DEFENSE

The Defense R&D program is oriented toward the development of strategic and tactical weapons and supporting systems to provide for the Nation's defense. DOD obligations for the conduct of R&D in 1984 would total $29.9 billion, an increase of $6.7 billion over 1983. Within the total, funding for basic research would increase by $98 million to $867 million in 1984. R&D facilities funding would total $438 million, up from $323 million in 1983. Major R&D efforts by DOD mission category in 1984 include:

Technology Base and Advanced Technology Development.—The purpose of these programs is to investigate promising new technologies and to avoid technological surprise by potential adversaries. The Very High Speed Integrated Circuits program will continue to push for further miniaturization of microelectronic devices. Increased attention also will be paid to human factors in the Defense mission. Protection against chemical agents, aids for use in training of personnel and exploration of the relation between man and machine will be stressed. Other areas of focus include information processing, materials research, fault-resistant electronics and advanced computer languages.

Strategic Programs.—In addition to the Peacekeeper and Trident II efforts, continued emphasis will be given to ballistic missile defense, an advanced technology bomber and an anti-satellite system. The communications and control systems that are needed for these and existing systems will also receive increased emphasis.

Tactical Programs.—Systems are under development that will improve the capability of U.S. general purpose and theater nuclear forces, and allow the rapid deployment of those forces wherever the vital interests of the U.S. are threatened.

- The Army is continuing work on upgrades to the M-1 tank and Bradley Fighting Vehicle System and is increasing its efforts on remotely piloted vehicles and some areas of air defense.
- The Air Force is developing a deep strike interdiction version of an existing fighter aircraft, a more reliable fighter engine, an air-to-air missile and a new trainer aircraft for undergraduate pilot training.
- The Navy is developing a lightweight anti-submarine torpedo, a new longer range anti-submarine missile and a new destroyer. Upgrades to current subsystems to improve detection, tracking and targeting will also increase the capability of major systems now in production.

Intelligence and Communications, Program Management and Support.—R&D on intelligence and communication systems will focus on communication satellites, on radios that will work in the electronic noise of the battlefield, and on surveillance radars. Work will also continue on the use of technology to reduce manufacturing costs and to extend the life and capability of existing defense systems.

Table K-5. **DEPARTMENT OF DEFENSE—MILITARY RESEARCH AND DEVELOPMENT**

(In millions of dollars)

Type of activity	1982 actual	1983 estimate	1984 estimate
OBLIGATIONS			
Conduct of R&D:			
Research, development, test and evaluation:			
Technology base	2,945	3,137	3,555
Advanced technology development	750	826	1,211
Strategic programs	4,846	5,747	8,978
Tactical programs	6,750	7,222	8,705
Intelligence and communications	2,104	2,686	3,474
Program management and support	2,538	2,869	3,236
Other appropriations	642	692	722
Total conduct of R&D	20,576	23,179	29,882
Total conduct of basic research, included above	(686)	(769)	(867)
R&D facilities	290	323	438
Total obligations	**20,866**	**23,502**	**30,320**
OUTLAYS			
Conduct of R&D	18,201	21,847	26,844
R&D facilities	232	289	349
Total outlays	**18,432**	**22,136**	**27,194**

NATO Cooperation.—Cooperation in research and development and joint production of new weapon systems will be pursued to make the best use of Alliance resources. Funding for these activities is not identified separately in Table K-5 but is included in the other categories listed in that table.

Table K-5 provides the details of the Department of Defense military R&D funding.

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Through the programs of NASA, the Federal Government develops and operates the Shuttle based Space Transportation System and makes investments in R&D that yield other new space technologies to improve the national security and the long term scientific and technological strength of the Nation. NASA programs also provide new knowledge about the Earth, the solar system, and the universe.

Now that the Space Shuttle is in its operational phase, it is no longer appropriate to classify all of NASA programs as R&D. Therefore, the amounts shown for 1982, 1983, and 1984 for NASA R&D exclude funding for Shuttle production and operation, tracking and data acquisition activities, and related institutional support.

In 1984, R&D obligations for the agency will decrease slightly due to spending patterns on previously initiated projects, although new obligational authority for R&D activities is projected to increase by $44 million. Basic research obligations by NASA in 1984 would amount to $682 million, an increase of $77 million over 1983. Obligations for construction of R&D facilities in 1984 would total $156 million.

Space Transportation.—With the initiation of Space Shuttle operations in November 1982, the major R&D phase of the Shuttle program has been concluded. A fully operational and cost effective Shuttle is essential to exploit space effectively and to help maintain U.S. leadership in space throughout this century.

Space Transportation R&D activities provided by the 1984 budget include Shuttle modifications and improvements and continued development of two versions of the Centaur upper stage—a new high energy upper stage for use with the Shuttle. Also included will be a tethered satellite program to extend the use of the Shuttle to conduct scientific experiments in the boundary region between space and the Earth's upper atmosphere. The tethered satellite will be an international cooperative program with the Italian government.

Space Science.—In this area, spacecraft in flight are conducting deep space astronomical observations from Earth orbit or exploring the solar system.

- The High Energy Astronomy Observatory (HEAO), launched in 1979, will continue operations and data analysis activities.
- Two Voyager spacecraft, launched in 1977, have successfully encountered Jupiter and Saturn, and Voyager 2 will continue on its way to Uranus for an encounter in 1986.
- The flight of several other smaller scientific satellites (e.g., International Ultraviolet Explorer) will be continued.

The 1984 budget supports continuation of the flight of these satellites in space and the analysis of scientific data sent back to Earth. It also provides for the retrieval and repair in orbit of the partially disabled Solar Maximum Mission Satellite.

The proposed budget continues development of major flight projects to be launched in the future.

- The Space Telescope is planned for launch in 1985 and will serve as a major astronomy facility for a 15- to 20-year period.
- The Gamma Ray Observatory is planned for launch in 1988 and will enhance basic research in high energy astrophysics, providing new knowledge about objects in deep space.
- Spacelab astronomy experiments, designed for repeated use, will be conducted on the Shuttle to improve our understanding of the Sun and the universe.
- Work is continuing on the Galileo mission to Jupiter; the spacecraft is composed of two segments—an orbiter and a probe to enter the upper atmosphere of Jupiter. The Galileo orbiter and probe will be launched in 1986 and will arrive at Jupiter in 1988 to carry out long-term studies of the planet, its satellites, and its magnetosphere.

In 1984, funds are also proposed to initiate the Venus Radar mapper project, for a 1988 launch, to map the planet. A new Explorer class project for research in ultraviolet astronomy will also be initiated, recognizing the potential of lower cost missions to conduct important science experiments in space.

Space and Terrestrial Applications.—The 1984 budget continues to support research that could lead to the broad application of space technology to national needs. The 1984 budget proposes continued funding for space-related research activities to:

- Improve understanding of Earth resources, climate, weather, and pollution;
- Advance knowledge in materials science and materials processing through low gravity experiments in space;
- Extend the capability for satellite communications to higher frequencies than those employed with current satellites;

The 1984 budget reduction for Space and Terrestrial Applications reflects decreasing obligations in two major projects that are nearing completion, Landsat and the Earth Radiation Budget Experiment (ERBE). However, the budget also includes increasing obligations for an Advanced Communications Technology Satellite (ACTS), while funding for other continuing programs will be maintained at about the same level as in 1983.

Landsat D, the fourth in the series of experimental Earth observing satellites, was launched successfully in July 1982 and is performing satisfactorily. A follow-on satellite will be completed in 1984, ready to succeed Landsat D when needed. Space remote-sensing technology, such as that employed by Landsat D, has the potential to improve our ability to manage critical Earth resources.

The ERBE satellite will be launched by the Shuttle in 1984. The program is designed to provide global measurements of the level of solar and cosmic radiation absorbed by the Earth and also map levels of ozone and other aerosols in the stratosphere. Such observation will help improve our understanding of the factors that determine the Earth's climate.

TABLE K–6. **NATIONAL AERONAUTICS AND SPACE ADMINISTRATION—RESEARCH AND DEVELOPMENT**

(In millions of dollars)

Type of activity	1982 actual	1983 estimate	1984 estimate
OBLIGATIONS			
Conduct of R&D:			
Space transportation systems	890	117	183
Space science	582	752	779
Space and terrestrial applications	319	398	289
Aeronautical research and technology	258	313	300
Space research and technology	118	131	138
Tracking and data acquisition	12	8	22
Research and program management	905	787	762
Total conduct of R&D	3,084	2,506	2,473
Total conduct of basic research, included above	(538)	(605)	(682)
R&D facilities	92	160	156
Total obligations	**3,176**	**2,666**	**2,629**
OUTLAYS			
Conduct of R&D	3,220	2,386	2,421
R&D facilities	109	136	129
Total outlays	**3,329**	**2,522**	**2,550**

The development of the ACTS will be a joint venture of government and industry and will provide advanced, higher frequency, satellite communications technology for use later in the decade.

Aeronautical Research and Technology.—The 1984 budget includes funds for a significant enhancement in new obligational authority for research in fundamental aeronautical disciplines such as fluid and thermal physics, materials and structures, and propulsion. In addition, technology development at the concept, technique or component level would also be enhanced. Planned obligations for aeronautical R&D will decrease slightly in 1984 because of the extraordinary rate of obligations against prior year authority experienced in 1983. New budgetary authority would increase from $280 million in 1983 to $300 million in 1984.

Funds are included for initiating in 1984, the development of a numerical aerodynamic simulation capability which will further the state-of-the-art of aerodynamic research and design and will also be an important tool for research in areas such as climate modeling and computational chemistry.

The 1984 budget also provides for research and technology development related to the use of composite materials in large aircraft structures. These lightweight materials would result in longer-range and more efficient military and civil aircraft.

Agency-wide support activities.—Obligations for agency-wide support activities would remain at about the 1983 level. These programs include primarily NASA civil service and administrative costs supporting R&D activities, construction and maintenance of the agency's R&D facilities, and R&D addressing fundamental space technology problems and opportunities common to a wide spectrum of space programs.

Table K-6 provides the details of NASA's R&D funding.

ENERGY RELATED ACTIVITIES

Energy related R&D, currently supported by the Department of Energy, covers a broad range of activities: a ***National Defense Program*** related to the development and testing of nuclear weapons: a ***General Science Program*** of basic research in high energy physics and nuclear sciences; and an ***Energy Program*** focused on long-term R&D. Table K-7 provides summary information on the funding of these programs.

Obligations for the conduct of energy related R&D (including facilities) are estimated to total $5.2 billion in 1984, a decrease of $117 million from 1983. Obligations in 1984 for R&D facilities, including the construction or upgrading of laboratories and other research support facilities, will amount to $501 million.

Obligations for the conduct of basic research, included in the total for the conduct of R&D, are estimated to be slightly over $1 billion in 1984. This represents an increase of $160 million, or more than 18% over the 1983 level. Within the basic research total, $82 million would be provided to initiate a number of major new projects in both the Energy Program and the General Science Program, that will significantly improve the Nation's capacity for basic research at the frontiers of science. These include:

- initiation of a national advanced materials research center at the Lawrence Berkeley Laboratory to improve the linkages among academic, national laboratory, and industry scientists for the future advancement of high technology industries;
- expansion of the National Synchrotron Light Source at Brookhaven National Laboratory to meet the growing need of industry, national laboratories, and universities for this research tool;
- building on a rapid time scale, a linear colliding beam accelerator at the Stanford Linear Accelerator Center to demonstrate the feasibility of new techniques for very high energy electron-positron collisions;
- upgrading of on-campus Van de Graaff accelerators at the University of Washington and Yale University to maintain the performance capabilities of two essential components of the university based nuclear physics research program; and
- a $6 million university instrumentation procurement program to provide large state-of-the-art equipment used in energy-related research areas.

Highlights of the Energy related R&D activities by major programs are provided below:

The ***National Defense Program*** primarily supports the continued development and testing of nuclear weapons. It also supports the development of improved technologies for monitoring nuclear weapons treaties and of improved methods for safeguarding nuclear materials. In addition R&D efforts will continue in developing methods for the safe storage and disposal of radioactive wastes resulting from weapons production, and research on improved propulsion reactors for naval vessels. Obligations for the National Defense Program for the conduct of R&D will increase from $1.7 billion in 1983 to $1.9 billion in 1984. Funds for R&D facilities in 1984 include construction of the Waste Isolation Plant (WIPP) in New Mexico for R&D on disposal of nuclear waste. Conduct of R&D increases provide funds for staff additions to strengthen the national weapons laboratories, for increased weapons tests, and for increased research in the basic physics of nuclear weapons.

The ***General Science Program*** supports research in high energy and nuclear physics. An increase of $90 million, to $643 million in 1984, for the conduct of basic research will continue support for advanced accelerator concepts as well as for theoretical efforts to understand the basic constituents of matter and energy and the forces that govern their interaction. Because of the exceptional research opportunities in high energy physics and the demonstrated excellence of the U.S. program, the Administration is committed to maintaining a strong national effort in this field. The 1984 budget request would provide for (a) increased utilization of existing accelerator facilities, (b) operation of the newly completed (1983) Energy Saver Superconducting Synchroton at Fermilab in the 500–1,000 GeV energy range, and (c) continuation of the construction at Fermilab of the Tevatron I and II projects which will provide increased proton-fixed target and proton-antiproton colliding beam capabilities. Funds will also be provided for upgrading accelerators at Yale University and the University of Washington and for initiation of the Stanford Linear Collider (SLC).

The ***Energy Program*** is focused in 1984 on long-term R&D to complement industry investments in new or improved energy technologies. It supports basic and generic research to enhance the scientific base for future advances in these technologies and continues support for the development of selected technologies of a high risk but potentially high payoff nature, such as magnetic fusion, where significant private investment is unlikely. In addition, the Energy Program includes research on the environmental and human health effects of energy production technologies. Energy Program obligations for the conduct of R&D would decrease from $2.4 billion in 1983 to $2.2 billion in 1984, largely reflecting net savings from proposed reductions in non-nuclear technology development and demonstration activities. Obligations for R&D facilities in this area would be $152 million, a reduction of $84 million, paralleling the reduction in the conduct of R&D.

In the *basic energy sciences,* funding for the conduct of R&D and related facilities will increase by $67 million to $350 million in 1984 for research in such fields as nuclear science, chemistry, engineering, materials science, mathematics, biology, and geoscience. This program provides the fundamental scientific and technical base for future advances in technology development. In addition, it provides support for the operation of several unique national facilities such as the National Synchrotron Light Source (NSLS) at the Brookhaven National Laboratory, the High Voltage Electron Microscope at Lawrence Berkeley Laboratory (LBL), and the Electromagnetic Isotope Separation Plant (calutrons) at Oak Ridge National Laboratory. In 1984 a national materials research center at LBL and an upgrade of the NSLS facility will be initiated.

The 1984 budget will continue the redirection of the non-nuclear R&D programs to limit federal support to long-term generic research and place greater reliance on the private sector for support of nearer-term technology development. Obligations for the conduct of R&D in the *fossil, solar* and *conservation* programs are expected to be $302 million in 1984, a decrease of $405 million from 1983.

Funding for the conduct of *fossil* related R&D and associated facilities would be $138 million in 1984, a decrease of $234 million.

The 1984 budget is focused on research to strengthen the technical base for future fossil technology development. Support would continue to be provided in such areas as the chemistry of coal conversion, environmental controls, combustion research, and the understanding of the behavior of oil and gas reservoirs.

Research in support of *solar* energy, proposed at a level of $87 million, will emphasize materials development for a variety of applications and continue to support research in the areas of solar thermal, photovoltaics, biomass, and wind conversion. In 1983, work on the international SOLERAS agreement will be completed. Research to foster energy *conservation* will be focused on improved understanding of energy losses in building systems, research on alternative heat engines, and development of advanced technologies for electrical systems and energy storage. Technology demonstrations in industrial, transportation, and buildings and community systems conservation will be scaled down in 1984. Conduct of R&D for energy *conservation* in 1984 would be $84 million.

The 1984 budget provides for a broad program of research in fission and fusion energy sources R&D. In the *magnetic fusion* program, funding of $467 million for the conduct of R&D and associated facilities would enable the continuation of investigations, at about the 1983 program level, of key physics issues involved with confined plasmas and further research on superconducting magnets, high power radiofrequency electronics, advanced materials development, and mathematical computer modeling needed for fusion technology development.

Within the fission effort the *breeder reactor* program will be funded at $603 million in 1984, maintaining a priority for the design and construction of the Clinch River Breeder Reactor (CRBR). In addition, long-range research will continue in support of breeder technology. Total funding for the conduct of breeder R&D will increase by $62 million over 1983. Other nuclear fission research areas such as *nuclear fuel cycle, converter reactors systems, and advanced nuclear systems* are funded for conduct of R&D and associated facilities at a level of $129 million for 1984.

Additional funds are proposed for nuclear safety and *commercial nuclear waste* management research. For example, in cooperation with the Nuclear Regulatory Commission, technical investigations associated with the disabled Three Mile Island nuclear power reactor will be supported. The fission R&D program will also seek to resolve technical issues associated with the construction of a permanent repository for nuclear waste. Obligations for these activities in 1984 will total $69 million.

Finally, the Energy Program supports R&D to determine the biological and environmental effects of energy production and use. The *biological and environmental research* R&D emphasizes the health effects of radiation, the use of radiation in medical diagnosis and therapy, and generic biological research related to radiation and other cellular traumas. The level of obligation for such activities will be $158 million in 1984. This effort also supports research to determine the relationship between the CO_2 content of the atmosphere and the earth's climate changes. Funding in 1984 for CO_2 studies will total $12 million.

Table K-7. **ENERGY RELATED ACTIVITIES** [1]

(In millions of dollars)

Type of activity	1982 actual	1983 estimate	1984 estimate
OBLIGATIONS			
Conduct of R&D:			
National defense program	1,526	1,727	1,905
General science program	500	553	643
Energy program	2,731	2,432	2,165
Total conduct of R&D	4,758	4,712	4,713
Total conduct of basic research, included above	(777)	(861)	(1,021)
R&D facilities	762	619	501
Total obligations	**5,519**	**5,331**	**5,214**
OUTLAYS			
Conduct of R&D	4,974	5,012	4,911
R&D facilities	804	623	532
Total outlays	**5,778**	**5,635**	**5,443**

[1] These programs, currently supported by the Department of Energy, will be proposed for reassignment to other Executive departments and agencies

DEPARTMENT OF HEALTH AND HUMAN SERVICES

The Department of Health and Human Services (HHS) obligations in 1984 for the conduct of R&D would increase by $100 million over the 1983 level to a total of $4.4 billion. Within this total, funding for basic research is estimated to be $2.2 billion. Obligations for R&D facilities would total $29 million in 1984. This represents a decline from the $60 million provided in 1983. The higher level of obligations in 1983 was primarily due to the nonrecurring costs for a single large project—construction of the new research headquarters for the Food and Drug Administration.

Health.—Over 87% of the Department's funds for the conduct of R&D and over 93% of the Department's basic research funds would be obligated by the National Institutes of Health (NIH) for biomedical research to advance the Nation's capabilities for the prevention, diagnosis, and treatment of disease. Several other agencies within the Department—the Alcohol, Drug Abuse, and Mental Health Administration, the Food and Drug Administration, the Centers for Disease Control, the Health Resources and Services

Administration, the Health Care Financing Administration, and the Office of the Assistant Secretary for Health—also support R&D programs in health related research.

The *National Institutes of Health (NIH)* consist of 11 separate Institutes which would obligate $3.8 billion in 1984 for the conduct of R&D, an increase of $71 million above the 1983 level; over one-half or $2.1 billion of NIH's total 1984 R&D budget would support basic research. Among the most significant activities to be supported by NIH are:

- Basic research on cancer chemoprevention including studies of nutritional factors; rehabilitation of patients with chronic obstructive pulmonary disease; prevention of glaucoma; diagnostic imaging, and the biological response to mixtures of chemicals;
- Clinical research where the emphasis is on intervention, including prototype development and refinement of products, techniques, processes, methods, and practices;
- Expansion of cooperative clinical trials on the acquired immunodeficiency syndrome/Kaposi Sarcoma problems; isolated systolic hypertension in the elderly; herpes simplex virus vaccine; and antiviral drugs against neonatal herpes, herpes encephalitis, herpes genitalis; the efficacy of interferon for controlling the frequency and severity of multiple sclerosis; gonococcal vaccines and the prevention of premature labor and the role of folic acid in neural tube defects; and
- Greater emphasis on basic clinical research into the cause, cure, and prevention of diabetes.

The *Alcohol, Drug Abuse and Mental Health Administration (ADAMHA)* conducts studies on the causes, prevention and treatment of alcohol and drug abuse and mental disease and neurological disorders, with emphasis on improving knowledge of effective prevention of these public health problems.

The 1984 budget proposes increases in levels for extramural research programs in biomedical, behaviorial and clinical areas. Obligations for ADAMHA would increase in 1984 to $314 million, an increase of $36 million over 1983.

Specific research areas would address:

- Neurosciences, behavioral sciences, psychopharmacology, and clinical investigations and evaluations of services to the mentally ill, with special emphasis on preventing and diagnosing mental and emotional problems in children;
- Drug abuse among the Nation's youth, including studies on the adverse health hazards of marihuana and cocaine; and
- Causes and consequences of alcohol abuse, particularly among teenagers.

The *Food and Drug Administration (FDA)* supports research relevant to its mission of regulating food, drugs, and biological and radiological products. In 1984, obligations for these activities are estimated at $82 million.

The *Centers for Disease Control (CDC)* supports studies on the epidemiology and control of communicable diseases and on health promotion and disease prevention. In 1984, obligations for these activities are estimated at $75 million.

Other Health Related Agencies within HHS would support research in areas such as how socioeconomic facts affect social security programs and the economy; survey methods and techniques for analysis of health statistics; and the organization, delivery, and financing of health services. This support will be provided through programs of the Health Resources and Services Administration, the Office of the Assistant Secretary for Health and the Health Care Financing Administration.

Human Services.—The Department's obligations for R&D in human services programs in 1984 would be $53 million, $11 million below 1983. The proposed 1984 budget would support a variety of developmental and social service research aimed at improving the Head Start program; the quality of life for the elderly; knowledge of child abuse and neglect; day care systems; family and community support systems and fostering independence for the disabled.

Table K-8 provides the details of the R&D funding of the Department of Health and Human Services.

NATIONAL SCIENCE FOUNDATION

The National Science Foundation (NSF) supports primarily basic research in all scientific disciplines through grants to scientists and engineers in academic institutions. NSF programs serve to advance scientific knowledge. Foundation support is particularly important because it complements the basic research programs of other agencies and assists in balancing Federal support for promising research across all fields of science and engineering.

The 1984 NSF budget includes $1.2 billion in obligations for the conduct of R&D, an increase of $180 million or 17 percent above 1983. This would provide a growth of about 12 percent in addition to cost increases due to inflation. Within this increase, support for the conduct of basic research would increase by about 18 percent. Specifically, the 1984 budget would:

- Provide special emphasis on disciplines such as mathematics, materials science, astronomy, and electrical, computer, and chemical engineering. Research in these disciplines has the potential to make important contributions to the long term

Table K-8. **DEPARTMENT OF HEALTH AND HUMAN SERVICES—RESEARCH AND DEVELOPMENT**

(In millions of dollars)

Type of activity and organizational units	1982 actual	1983 estimate	1984 estimate
OBLIGATIONS			
Conduct of R&D:			
Health:			
National Institutes of Health	3,432	3,771	3,842
Alcohol, Drug Abuse, and Mental Health Administration	243	278	314
Food and Drug Administration	73	77	82
Centers for Disease Control	75	70	75
Health Resources and Services Administration	12	10	1
Health Care Financing Administration	29	30	30
Office of the Assistant Secretary for Health	16	16	18
Subtotal, Health	3,879	4,252	4,362
Human Services:			
Office of Human Development Services	26	23	11
Social Security Administration	17	26	31
Departmental Management	13	15	11
Subtotal, Human Services	56	64	53
Total conduct of R&D	3,935	4,316	4,416
Total conduct of basic research, included above	(1,953)	(2,184)	(2,238)
R&D facilities	29	60	29
Total obligations	**3,964**	**4,376**	**4,444**
OUTLAYS			
Conduct of R&D	3,978	4,262	4,339
R&D facilities	38	31	35
Total outlays	**4,015**	**4,292**	**4,374**

competitiveness of the U.S. economy, particularly in high technology dependent industries.

- Provide $180 million in 1984, an increase of 61% over 1983, for upgrading research instrumentation primarily at universities. This sharp increase is included within the support for the conduct of basic research. Along with funds provided for this purpose in other agencies, the increase in the NSF budget would enhance research productivity by helping to alleviate the problem of growing obsolescence of research instrumentation at universities. It would also help ensure that future scientists and engineers are trained in the use of modern research instrumentation and techniques.
- Fund the continuation of the deep sea drilling project to provide scientific geologic information related to the Earth's crust, ocean sediments, geochemistry and paleontology.

In addition, the 1984 budget proposes increased funding in the U.S. Antarctic program for improvement of logistic support. These improvements are critical to the conduct of a safe and effective research program and to the maintenance of an active and influential U.S presence in Antarctica

DEPARTMENT OF AGRICULTURE

The Department of Agriculture supports research and development in several disciplines related to agriculture and forestry.

Obligations of the Department for the conduct of research and development are estimated to total $849 million in 1984, a decrease of $1 million from 1983. Of the total, $381 million would support basic research, an increase of $19 million over the 1983 expected obligations of $362 million.

The Department's 1984 budget is highlighted below by major bureau:

The Agricultural Research Service (ARS) would obligate $458 million for research designed to produce new knowledge and technologies required to assure the continuing vitality of the Nation's food and agriculture enterprise. This represents an increase of $12 million over 1983.

In 1984, increased emphasis would be placed on genetic engineering in the plant and animal sciences, human nutrition research, and improved post-harvest technologies. In addition, a new program of post-doctoral fellowships in ARS laboratories would be initiated. Short term applied research and development would continue to receive reduced Federal effort, since such activities are more appropriately financed by the private sector.

The Cooperative State Research Service would obligate $222 million to maintain support of the cooperative program with institutions in 50 States, the District of Columbia, Puerto Rico, Guam, the Virgin Islands, American Samoa and Micronesia engaged in research in agriculture, forestry, veterinary medicine, and the rural home and the community. Also, the budget would continue the competitive grants program in basic research important to increasing the efficiency of food production and improving human nutrition. For the first time, competitive grants for research in the animal sciences would be made.

The Forest Service would obligate $101 million, a decrease of $4 million from 1983, to provide knowledge needed to manage and protect forest and related rangeland resources to gain maximum economic and social benefits from their use. Research would be conducted on: genetics; silviculture and timber management; watershed management; wildlife, range and fish habitats; protection for forest resources from fire and forest pests; surface environment and mining; forest engineering and utilization; and economics of forest commodity production, processing and distribution.

In addition, $68 million would be obligated in other departmental programs for economic research, international cooperation and development, transportation of commodities, nutrition information, and statistical reporting.

DEPARTMENT OF COMMERCE

The Department of Commerce has responsibility for ocean science and engineering research, meteorological research and forecasting, and for maintaining measurement standards. The 1984 budget would continue these programs in the National Oceanic and Atmospheric Administration (NOAA), the National Bureau of Standards (NBS), and other areas of the Department.

Obligations for the conduct of R&D by the Department in 1984 are estimated at $227 million, a decrease of $86 million from 1983. This decrease applies largely to relatively nearer term applied research and development, more appropriately the responsibility of the private sector.

National Oceanic and Atmospheric Administration (NOAA).—NOAA would continue R&D programs to develop systems and components for nautical and aeronautical mapping and charting; ocean engineering systems in support of NOAA ocean research and operational programs; better ways to conserve, protect, and manage the Nation's fishery resources; new and improved fishing equipment to protect endangered and/or threatened species; and timely and accurate meteorological, hydrologic, and oceanographic forecasting, detecting and tracking systems for protection of life and property. Obligations for the conduct of R&D by NOAA in 1984 would decrease from $194 million to $135 million. This reduction reflects decreases in applied areas, more appropriately supported by the private sector.

National Bureau of Standards (NBS).—R&D efforts for NBS are aimed at developing and maintaining a system of measurement required to support the Nation's industrial and scientific endeavors.

In 1984, NBS is expected to obligate $78 million for the conduct of R&D. This represents a $16 million decrease from 1983. Funding for the following programs would be terminated or reduced on the grounds that such research can and should be supported by the private sector: fire science and engineering ($6 million), building research ($3 million), ADP standards ($6 million), and recycled oil ($1 million).

Other Commerce R&D Activities.—Funding for smaller research and development programs in the Department of Commerce, which include those in the Bureau of the Census, the Patent and Trademark Office, and the National Telecommunications and Information Administration, would be $14 million in 1984.

DEPARTMENT OF THE INTERIOR

The R&D activities of the Department of the Interior derive from its broad-ranging responsibilities for management of the Nation's natural resources, including developing energy and mineral resources, restoring and preserving wildlife habitats and wilderness areas, and improving the quality of our water resources.

Obligations for the conduct of R&D for the Department of the Interior for 1984 are estimated at $329 million. This represents a decrease of approximately $44 million from the 1983 level, primarily in applied mining and applied geological research.

Almost 90% of the Department's 1984 funds for the conduct of R&D would be obligated by the Geological Survey ($136 million), Fish and Wildlife Service ($89 million), and Bureau of Mines ($68 million). Highlights of the 1984 research objectives of these and other departmental programs are described below.

The *Geological Survey* undertakes research on the extent, distribution, and character of the Nation's natural resources and on the geologic processes, structures, and hazards that affect the development and use of the land and physical environment. Research priorities in 1984 would include continued development of:

- Accurate appraisals of land and mineral resources;
- New and improved methods of mineral exploration;
- An improved scientific basis for investigation and measurement of water resources; and
- Basic data on geologic principles and processes.

The *Fish and Wildlife Service* supports research performed in the Service's laboratories and field stations, and through cooperative efforts with State fish and game departments. It also provides Federal aid to States for research on restoration of fish and wildlife resources. This research provides basic biological information about species numbers, population dynamics, ecological relationships, and habitat requirements. In 1984, the Service would support research activities concerned with:

- The habitat of waterfowl, migratory birds, mammals and non-migratory birds;
- Endangered and threatened species status, distribution and threats;
- Impact of broad-scale environmental changes on fish and wildlife populations and habitat; and
- Fish husbandry and aquaculture.

The *Bureau of Mines* conducts basic and applied research across the minerals cycle to improve our understanding of the principles of mining and minerals processing, and to reduce associated health hazards. Reductions are proposed in applied research, particularly in projects of a commercial nature which are more appropriate for the private sector to support. Basic research is proposed to increase by 22% through reallocations of funds from applied research projects. The 1984 budget reflects an increased emphasis on strategic and critical minerals R&D activities and would stress:

- Long-range, high-risk research in extractive metallurgy technology that may result in new processing methods;
- Development of domestic source substitutes for imported strategic and critical minerals;
- Health-related research on the proper quality and quantity of air flow in underground mines; and
- Longer-term, generic research on fire and explosion prevention, methane and underground control, industrial hazards, post-disaster survival and rescue, explosives, and systems engineering.

Other Departmental Programs would provide for:

- Development of technology to generate additional water supplies by cloud seeding techniques; and
- Development of new materials, planning tools, design and construction techniques to solve problems arising in the development and operation of water resources projects.

DEPARTMENT OF TRANSPORTATION

The Department of Transportation's R&D program is oriented toward providing the information and new technology needed for its own operational (e.g., air traffic control) programs and for regulatory (e.g., automotive and aircraft safety standards) programs. Obligations for the conduct of research and development by the Department are estimated at $519 million for 1984, an increase of $126 million over 1983. The Department's 1984 budget for R&D, with explanations of major changes from 1983, is highlighted below by agency.

The Federal Aviation Administration would obligate $304 million in 1984. The proposed 1984 R&D obligations for FAA represent an increase over 1983 of $161 million. A major portion of this increase occurs in the advanced computer, aviation weather, communications and systems programs. This increase would allow greater emphasis on engineering work to enhance the safety and efficiency of the national air traffic control system, and on emerging technology to improve collision avoidance systems and enroute and terminal air traffic control systems.

The National Highway Traffic Safety Administration would obligate $57 million for motor vehicle research, traffic safety research and demonstrations emphasizing safety belt usage, alcohol counter measures, and for analytical studies. In 1984, a small increase is planned for highway safety research in support of the safety belt program. The National Accident Sampling System which provides for the collection and analysis of nationally representative accident and injury data would be continued.

The Urban Mass Transportation Administration would obligate $46 million to assist in the development of improved mass transportation systems, equipment and procedures. Emphasis would be placed on research aimed at improving the operation and maintenance of existing transit systems.

The Federal Highway Administration would obligate $49 million to continue research programs in highway planning, design, construction, and maintenance to insure an effective and efficient highway system. Research would also be conducted in identifying, and correcting impediments to highway safety and on improving truck safety.

The Federal Railroad Administration would obligate $17 million to continue highest priority safety research. This would result in more cost-effective safety compliance and enforcement techniques.

The Maritime Administration would obligate $13 million to improve the productivity and competitive posture of the U.S. maritime industries. This level is $4 million below the 1983 budget.

The U.S. Coast Guard would obligate $22 million to support research to maintain and improve search and rescue systems, environmental protection, marine safety, aids to navigation, and the enforcement of laws and treaties, and activities affecting all Coast Guard missions. The proposed 1984 figure represents an increase of $2 million above the 1983 level.

The Research and Special Programs Administration would obligate $5 million to support emergency preparedness and mobilization, hazardous materials and pipeline safety regulatory programs, and long range university research.

The Office of the Secretary would obligate $7 million for broad-based policy research on domestic and international transportation issues of importance to the Nation.

ENVIRONMENTAL PROTECTION AGENCY

The Environmental Protection Agency (EPA) conducts research and development in support of the Agency's regulatory and enforcement missions. For 1984, EPA's R&D program will focus on three major concerns: (1) better linkage of research to the Agency's regulatory priorities; (2) greater attention to quality assurance to improve the reliability of scientific data used in Agency decisions; and (3) restructuring the Agency's long-range basic research program.

Total obligations for EPA's R&D program in 1984 are proposed to be $208 million, a decrease of 14% from 1983. This reduction reflects completion of major research to support regulatory decisions and reductions for development of pollution control technologies. EPA's major research activities are highlighted below.

The acid rain/energy research program will be increased to understand better the phenomena of acid deposition. Specifically, a comprehensive atmospheric field study will be initiated, dry deposition monitoring will be accelerated, and watershed research studies will be expanded. Research in support of the Limestone Injection Multistage Burner (LIMB) control technology will be continued.

The hazardous waste research program will support efforts on land disposal of hazardous waste, post-closure monitoring of land disposal facilities, screening protocols for hazardous wastes, and research support for permitting hazardous waste disposal facilities.

The Superfund research program will maintain its research efforts at 1983 levels. However, funding will shift from engineering activities to monitoring and environmental effects research which are closely associated with current field work at hazardous waste sites. Funds for this research program are derived from the Hazardous Substance Response Trust Fund which is funded primarily by a tax on oil and chemical industries.

The drinking water research program will strengthen risk assessments, health research, and monitoring for the Drinking Water Program. Resources for groundwater transport and fate research are maintained at 1983 levels. Work will continue on revising the Primary Drinking Water regulations.

The air research program will continue the development of comprehensive health risk assessments for hazardous air pollutants, improve monitoring methods for sampling and analyzing non-criteria organic pollutants and improve air quality dispersion models.

The water quality research program will emphasize research on ocean dumping and water-quality based pollution control requirements. In the municipal wastewater area, research will focus on innovative and alternative wastewater treatment technologies and more efficient sludge management techniques. Industrial wastewater research will be reduced reflecting completion of the effluent guidelines effort and will be refocused to support the waste water permitting program.

The toxic substances research program will increase development of health risk assessment models. Total research funding is slightly lower in 1984 reflecting the completion of a major monitoring study and completion of engineering technical support for the review of chemicals.

The interdisciplinary research program will continue to support the Agency's research centers, long-term research grants, and development of economic benefits methods.

NUCLEAR REGULATORY COMMISSION

The Nuclear Regulatory Commission (NRC) performs research in civil uses of nuclear materials and facilities consistent with public health and safety, environmental quality, and national security. A major share of NRC's effort is devoted to research connected with the use of nuclear energy to generate electric power. Its research objective is to provide safety and analytical methods for assuring the quality of NRC's licensing procedures and regulatory work.

In 1984, NRC's obligations for the conduct of R&D are expected to decrease from $210 to $200 million. This reduction from 1983 is due primarily to the transfer of work at the Loss of Fluid Test Facility (LOFT) to an international consortium. Key areas, such as accident evaluation and mitigation and systems reliability analysis will be strengthened. In addition, reactor safety research, principally on the Clinch River Fast Breeder Reactor, will be continued.

VETERANS ADMINISTRATION

The Veterans Administration (VA) conducts and administers medical, rehabilitation, and health services research. In 1984 this agency would obligate $163 million, for the conduct of R&D.

The VA *intramural biomedical research program* is designed to benefit patients through increased quality and effectiveness of health care delivery. Priorities for 1984 include special research on Agent Orange, alcoholism, aging, and post-traumatic stress.

In *rehabilitation research*, the VA focuses on problems in the field of prosthetics, orthotics, wheelchairs, spinal cord injury and sensory aides for improving the care and rehabilitation of disabled veterans, including amputees, paraplegics and the blind.

The *health services research program* supports projects at VA facilities to improve the effectiveness, economy, and accessibility of health care services. In addition, emphasis will be placed on research relevant to health care delivery to veterans and the services provided to them.

AGENCY FOR INTERNATIONAL DEVELOPMENT

Research and development activities of the Agency for International Development (AID) consist mainly of applied research to solve specific problems associated with basic human needs and social and economic research aimed at improving U.S. and host country understanding of the barriers to development.

Obligations of AID for the conduct of R&D are estimated at $161 million in 1984, an increase of $9 million over 1983.

Programs under AID reflect the administration's recognition of the importance of R&D in addressing the problems faced by the Third World.

The majority of AID's 1984 R&D funds will be devoted to three critical problems: food production, with an emphasis on affecting developing country efforts to overcome the growing food crisis; population growth, emphasizing methods of controlling increasing population growth rates in the developing countries; and energy supply, emphasizing renewable and nonconventional energy sources critical for development to proceed.

OTHER AGENCY PROGRAMS

An additional 9 departments and agencies (listed in table K-2, footnote 1) would obligate an estimated $418 million in 1984, for the conduct of R&D, an increase of $27 million over the 1983 total. Obligations by these agencies amount to less than 1% of all federally funded programs in R&D. The programs of these agencies, like those of other agencies discussed above, are closely related to the agencies' missions.

Among the agencies in this category that expect to increase their obligations for R&D in 1984 are the Smithsonian Institution, Housing and Urban Development, the Federal Emergency Management Agency, the Tennessee Valley Authority, and the Departments of Justice, Labor, and Treasury.

SUPPLEMENTARY INFORMATION

Table K-9 provides information on the long-term trends in Federal funding for the conduct of R&D.

TABLE K–9. TRENDS IN CONDUCT OF R&D

(Obligations in billions of dollars)

Year	Defense [1]	All other	Total
1953	2.8	.3	3.1
1954	2.5	.3	2.9
1955	2.2	.4	2.5
1956	2.5	.5	3.0
1957	3.3	.6	3.9
1958	3.8	.8	4.6
1959	5.6	1.1	6.7
1960	6.1	1.5	7.6
1961	7.0	2.1	9.1
1962	7.2	3.1	10.3
1963	7.8	4.7	12.5
1964	7.8	6.4	14.2
1965	7.3	7.3	14.6
1966	7.5	7.8	15.3
1967	8.6	7.9	16.5
1968	8.3	7.6	15.9
1969	8.4	7.2	15.6
1970	8.0	7.3	15.3
1971	8.1	7.4	15.5
1972	8.9	7.6	16.5
1973	9.0	7.8	16.8
1974	9.0	8.4	17.4
1975	9.7	9.3	19.0
1976	10.4	10.4	20.8
1977	11.9	12.1	24.0
1978	12.6	13.8	25.4
1979	13.6	15.4	29.0
1980	15.1	16.6	31.7
1981	17.8	17.2	35.0
1982	22.1	[2] 14.3	36.4
1983 (estimate)	24.9	[2] 14.0	38.9
1984 (estimate)	31.8	[2] 14.0	45.8

[1] Includes military-related R&D programs of the Departments of Defense and Energy

[2] Excludes NASA funding for shuttle production and operation, tracking and data acquisition activities, and related institutional support

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